The Journal of Raptor Research

Volume 37 Number 3 September 2003

THE RAPTOR RESEARCH FOUNDATION, INC.
(FOUNDED 1966)

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COVER: Red-shouldered Hawk (*Buteo lineatus*). Painting by James Coe. Visit www.jamescoe.com to view more of his artwork.

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BEHAVIOR AND PREY OF NESTING RED-SHOULDERED HAWKS IN SOUTHWESTERN OHIO

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ABSTRACT.—We used direct observations to quantify prey types, prey delivery rate, and adult and nestling behavior at nests of Red-shouldered Hawks (*Buteo lineatus*) in suburban southwestern Ohio. Twenty-one nests were observed for 256 hr in 1997–2001. Small mammals made up the largest percentage of the identified prey (31.5%), followed by reptiles (22.7%), invertebrates (18.8%), amphibians (17.7%), birds (6.9%), and fish (2.5%). Season-long prey delivery rate averaged 3.4 ± 0.6 prey items delivered per 4-hr observation period, or 116 ± 19 g biomass delivered per 4-hr observation period. Weekly prey delivery rate showed no correlation with the age of the nestlings ($P > 0.05$). Adult attendance at the nest and time adults spent brooding nestlings both were negatively correlated with nestling age ($P < 0.05$). Time adults spent feeding nestlings was negatively correlated with nestling age ($R^2 = 0.92$, $P = 0.002$), while time nestlings spent feeding themselves was positively correlated with nestling age ($R^2 = 0.92$, $P = 0.003$). These data may serve as a baseline for assessing prey delivery rates and behavior of populations of Red-shouldered Hawks throughout the lower Midwest.

KEY WORDS: *Red-shouldered Hawk*; Buteo lineatus; *behavior*; *diet*; *prey*; *raptor*.

CONDUCTA Y PRESAS DEL GAVILAN DE HOMBROS ROJOS DURANTE SU ANIDACIÓN EN EL DEL SUROESTE DE OHIO

RESUMEN.—Utilizamos observaciones directas para cuantificar las presas, su tasa de entrega y la conducta de adultos y polluelos en nidos de gavilanes de hombros rojos (*Buteo lineatus*) en las localidades suburbanas del suroeste de Ohio. Se observaron veintiún nidos durante 256 horas entre 1997–2001. El porcentaje más grande de presas identificadas estuvo representado por mamíferos pequeños (31.5%), seguido por reptiles (22.7%), invertebrados (18.8%), anfibios (17.7%), otros pájaros (6.9%) y peces (2.5%). El promedio de la tasa de entrega de presas a lo largo de la temporada fue 3.4 ± 0.6 ítems de presa entregados en un período de 4 horas de observación, o 116 ± 19 g de biomasa entregada, en un período de 4 horas de observación. La tasa semanal de entrega de presa no mostró correlación con la edad del polluelo ($P > 0.05$). La asistencia de los adultos en el nido y el tiempo empleado por los adultos empollando, estuvieron correlacionados negativamente con la edad del polluelo ($P < 0.05$). El

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tiempo que los adultos emplearon alimentando al polluelo tuvo una correlación negativa con la edad del polluelo (R^2 = 0.92, P = 0.002), mientras que el tiempo que gastaron los polluelos alimentándose a sí mismos tuvo una correlación positiva con su edad (R^2 = 0.92, P = 0.003). Estos datos pueden servir como una base para valorar las tasas de entrega de presa y la conducta de poblaciones de gavilanes de hombros rojos a través del Medio Oeste bajo.

[Traducción de César Márquez]

The diet of Red-shouldered Hawks (*Buteo lineatus*) has been documented in several locations using either observational data or prey remains in pellets or nests (Craighead and Craighead 1956, Portnoy and Dodge 1979, Bednarz and Dinsmore 1985, Howell and Chapman 1998), but only a few researchers have attempted to measure prey delivery rate by adult Red-shouldered Hawks to nestlings (Snyder and Wiley 1976, Portnoy and Dodge 1979, Penak 1982), and only one study has quantified and reported other behaviors of adults and nestlings during the breeding season (Portnoy and Dodge 1979).

Quantitative information on food delivery rates and adult and nestling behaviors is of particular interest because productivity may be related to prey delivery rate. Prey delivery rates are usually indicative of prey availability in the environment (Newton 1979, Collopy 1984) and food supply is generally the most significant factor determining breeding rates for raptors (Newton 1979). Adult and nestling behavior also may be influenced by prey availability, in that time spent foraging is a function of prey availability, and nestling growth and development may be related to food provisioning rate (Dykstra 1995).

Because of its restricted distribution due to habitat loss within the state of Ohio, the Red-shouldered Hawk is currently a "Species of Special Interest" in the state (Ohio Department of Natural Resources pers. comm.) and is similarly classified in other midwestern and eastern states (Titus et al. 1989, Castrale 1991). Prey delivery rates and other behavioral data for the Red-shouldered Hawk may be useful in evaluating the viability and conservation status of this species, particularly if they can be used as indicators of the adequacy of prey availability within an environment.

Our objectives were to quantify the prey delivery rate and other behaviors of adult and nestling Red-shouldered Hawks in southwestern Ohio from hatching through fledging. This information may be useful for comparison to other populations in the lower Midwest and other parts of the breeding range.

STUDY AREA AND METHODS

Study Area. The study area in southwestern Ohio is a hilly, unglaciated area in the Interior Plateau ecoregion (Omernik 1987). The hills are dissected by many small streams located in ravines and by two large rivers, the Great Miami River and the Little Miami River. Native forests are dominated by second-growth oak-hickory (*Quercus* spp., *Carya* spp.) and beech-maple (*Fagus grandifolia, Acer saccharum*) associations, with lowland, riparian forests characterized by sycamores (*Platanus occidentalis*) and beech. Elevation ranges from ca. 140–270 m.

The study area consisted of Hamilton County, Clermont County, and southwestern Warren County, Ohio, however, the nests studied were actually located in a wide band of suburban development surrounding the city of Cincinnati, Ohio. Suburban areas varied from densely-populated (residential lots ca. 20 × 35 m) to sparsely-populated (>2.5-ha residential lots, as well as undeveloped private land). Most residences and other buildings were surrounded by lawns and other nonnative vegetation, but residences tended to be located on level ground, with steep slopes and riparian areas left in native vegetation. Areas of public land within the study area contained no residences, but were heavily used for sports and other recreation.

Nests and Nest Selection. Nests in this study were selected from those known from a larger study of suburban Red-shouldered Hawk productivity and nest site selection (Dykstra et al. 2000a). We selected nests based on their visibility from a suitable blind location and their accessibility. Nests were selected for study after nestlings had hatched. We studied six nests in 1997, six nests in 1998, five nests in 1999, four nests in 2001 (Table 1). We observed for two or three breeding seasons at some nests (or at alternate nests within the same territory): two territories were each monitored in two years and two were each monitored in three years. Thus, we studied a total of 15 independent territories (Table 1); of these, five were located within or very near (225 m away, N = 1) the floodplain of the Little Miami River, and 10 were in upland locations, primarily near small streams. Observed nests were built primarily in sycamores (N = 12; 67%), but also in red oak (*Quercus rubra*; N = 2), white ash (*Fraxinus americana*; N = 1), sugar maple (*Acer saccharum*; N = 1), and common locust, (*Robinia pseudoacacia*; N = 1), and one nest was built on the roof of a three-story apartment building in a busy complex of such buildings (Hays 2000, Dykstra et al. 2001a). Mean height of the nests was 15.2 ± 0.8 m above the ground (N = 17 measured nests).

Nest Observations. At most sites, nests were observed from blinds made of camouflage-colored canvas and native plant materials, erected 31–85 m ($\bar{x}$ = 49 m) from the nests (N = 12). At other nests, we used temporary

Table 1. Observation schedules and reproduction at Red-shouldered Hawk nests studied 1997 to 2001.

Nest Name	Year	Number of 4-hr Observation Blocks	Age Observed (wk)	Brood Size[a]	Number of Young Fledged
Birch Rail Run	1999	4	2–6	2	2
Cones	1998	2	4	3	0
Fields-ertel	1997	4	2–6	2	2
Gaines	2001	2	6	2	2
Lake Bern	1999	4	2–5	4	3
Mapleknoll	2001	2	4	2	2
Maryknoll	1997	2	2–3	2	0
Nisbet	1997	4	2–6	3	3
Nisbet	1998	4	3–6	3	3
Nisbet	1999	4	1–5	3	3
North Wesselman	2001	3	2–6	4	4
Pineview	1998	3	1–6	3	3
Pineview	1999	3	1–4	3	3
Roof	1998	3	2–4	4	4
Sheed	1997	2	5–6	4	4
Sheed	1998	4	2–6	3	3
Sheed	1999	4	1–5	3	3
Tanager Hills	1997	2	1–2	4	0
Twin Willow	2001	1	5	2	2
Woodsong	1997	3	1–4	3	0
Woodsong	1998	4	1–5	1[b]	1

[a] Brood size during most observation periods. Brood size during wk 1 may have been smaller if not all chicks had hatched, or, possibly, larger.

[b] Brood size during wk 1 was 2 or 3 young.

blinds created from patio furniture ($N = 3$) or sat inside a vehicle parked on a driveway ($N = 4$). At two nests where birds were very accustomed to humans, no blinds were used. Where possible, we placed blinds upslope from the nests, improving the view of nest contents. We conducted observations during the brood-rearing periods, between 1 May and 3 June 1997, 27 April and 1 June 1998, 27 April and 5 June 1999, and 4 May and 10 June 2001. Each observation period lasted 4 hr; "morning" observations were conducted between 0700 and 1300 H ($N = 35$), "afternoon" observations were conducted between 1130 and 1800 H ($N = 28$), and a single observation was conducted 1000–1400. We observed most nests ($N = 14$) 3–4 times, approximately once per wk from the time of hatching until the first nestling fledged. Because three nests failed partway through the nestling period, we were unable to complete studies on them, and we added four nests partway through the season; these nests were observed 1–2 times each ($N = 7$; Table 1). We chose to observe fewer times at many nests rather than make intensive studies of a few nests in order to minimize the influence that individual birds/pairs might have on the behavior data.

We monitored and recorded behaviors of nestlings and adults, with the time of occurrence and duration (nearest min). The specific behaviors quantified were: adult attendance at the nest, adult prey delivery to nest, adult feeding nestlings, adult brooding nestlings, and nestlings

feeding themselves. We defined adult attendance at the nest as the total amount of time at least one adult was present in the nest itself. Adult feeding nestlings included all the time an adult fed one or more nestlings and all the time an adult fed itself and nestlings. Brooding behavior was defined as an adult covering 50% or more of the total number of nestlings. Nestlings feeding themselves included all time that 50% or more of the nestlings in the brood were feeding themselves.

We recorded prey deliveries by adults to the nestlings. We attempted to identify the taxonomic class and the size of each prey item. Prey were categorized into one of eight classes: amphibian, reptile, fish, bird, mammal, insect, crustacean, or oligochaete. Further identification to species or species-group was recorded if possible. Prey were also categorized to one of four size-classes: 0–15 cm, 16–30 cm, 31–46 cm, >46 cm; smaller size categories were recorded when possible.

Hatch date was estimated by back-calculating from the approximate age at banding, based on secondary length (Penak 1982), or by observation of adult behavior. The date of hatch of the oldest nestling was used when assigning nestling ages for data analyses. We defined Day 1 as hatch date and Week 1 as 1–7 d post-hatch.

Data Summary and Analyses. Total minutes spent in brooding, feeding, and adult presence at the nest were tallied, and reported as a percent of total time observed (240 min/session). Adult and nestling behaviors were re-

ported as a function of approximate nestling age in weeks. At five nests, we observed twice within a single week of nestling age; behavioral data at these sites were averaged to provide a single mean value for each week. Multiple years of data from territories observed in more than one year were considered to be independent for purposes of data analyses. We observed a total of 256 hr, 64 4-hr sessions.

We tallied the prey delivery rate at each nest each week (prey deliveries/nest/4-hr observation period), and pooled study nests by nestling age for a study-wide weekly prey delivery rate. We also calculated a season-long mean prey delivery rate for each nest.

Records of prey type and size were combined for all nests and all years. In addition, we included data on prey deliveries recorded during shorter observation periods (1–3.5 hr) totaling 44 hr, at eight nests 1998–2001. (Other behavioral data from these shorter observations were not included in the above analyses). Biomasses of prey items were estimated based on published data on Red-shouldered Hawk diet (Craighead and Craighead 1956, Howell and Chapman 1998) and other measures of prey item masses (Hiles and Jones 1941, Mohr 1947, Steenhof 1983, Jayne and Bennett 1990, Sibley 2000), as well as field measurements on prey items captured within the study area (C. Dykstra and J. Hays, unpubl. data). When the species of a prey item was unknown, but the genus or genus and size were known (e.g., *Microtus* vole, medium *Rana* frog), we used the mass of an appropriate species known to be present in the study area. For calculation of biomass-delivery rates, unidentified prey of the 0–15 cm size ($N = 20$) were assigned the mean mass for all identified prey size 0–15 cm (28 g), unidentified prey of the size 16–30 cm ($N = 2$) were assigned the mean mass for identified prey of size 16–30 cm (52 g), and unidentified prey of unknown size class ($N = 24$) were assigned the overall mean mass for all known prey items (36 g). Distributions of prey-size classes for identified and unidentified prey did not differ (Pearson Chi-square, $P > 0.05$).

Nestling and adult behaviors, including prey delivery rates, were reported as a function of nestling age (wk). Weekly values for each behavior at each nest were log-transformed to account for non-normality, then averaged to produce a study-wide weekly mean value. Study-wide weekly values were compared to nestling age using linear regression.

Season-long mean prey delivery rates, calculated in both numbers of prey items and estimated biomass, were log-transformed and compared to brood size using linear regression. Taxonomic classes of prey delivered at riparian zone nests and upland nests were compared using a Chi-square test for independent distribution; we combined prey items in classes Crustacea, Insecta, and Oligochaeta into the category "invertebrates," because the numbers of items in some of these classes were very small. When distribution of prey types differed, we used Bonferroni Z-test to examine which prey types were delivered more or less often than expected at the two habitats: flood plains or upland (Neu et al. 1974, Byers et al. 1984).

Results are presented as mean ± SE. All statistical tests were conducted using SYSTAT (Wilkinson 1988) and were considered significant at the $P < 0.05$ level.

RESULTS

Reproductive Rate. Red-shouldered Hawks at observed nests had reproductive rates of 2.2 ± 0.3 young per nest where eggs hatched ($N = 21$; Table 1) and 2.8 ± 0.2 young/successful nest ($N = 17$), which was similar to the rate we measured for the entire study area (2.7 ± 0.2 young per successful nest, 1997–99, Dykstra et al. 2000a).

Prey Deliveries. There was no difference in the number of prey items or estimated biomass delivered in morning observations and in afternoon observations (number of items: $t = 0.73$, df $= 61$, $P = 0.47$; estimated biomass: $t = 0.10$, df $= 61$, $P = 0.92$), so data from both observation periods were combined for analyses below. Sample sizes were insufficient to test for differences between years, so data from all observation years were combined. Weekly prey delivery rate showed no correlation to the age of the nestlings (number of prey items, $R^2 = 0.27$, $P = 0.29$, $N = 6$ wk, and estimated biomass, $R^2 = 0.23$, $P = 0.34$, $N = 6$ wk; Fig. 1). Season-long prey delivery rate averaged 3.4 ± 0.6 prey items delivered per 4-hr observation period, or 116 ± 19 g biomass delivered per 4-hr observation period ($N = 21$ nests). Season-long prey delivery rate was weakly correlated to brood size when delivery rate was measured as number of prey items ($R^2 = 0.14$, one-tailed $P = 0.048$, $N = 21$; Fig. 2); however, the relationship was dependent on one datum (which included an unusual day when 21 items, mostly earthworms, were delivered in 4 hr) and was not significant when that datum was removed ($R^2 = 0.07$, one-tailed $P = 0.14$, $N = 20$). Season-long prey delivery rate was not correlated to brood size when delivery rate was measured as estimated biomass ($R^2 = 0.07$, one-tailed $P = 0.13$, $N = 21$).

Eighty-two percent of all prey items delivered were identified to taxonomic class (203 of 249 deliveries). Small mammals (Class Mammalia) made up the largest percentage of the identified prey, in terms of numbers of items and biomass (Table 2) Thirty-two percent (65 of 203 deliveries) of identified prey items were further classified to species or genus (Table 2).

The types of prey items delivered to riparian nests differed significantly from those delivered to upland nests ($\chi^2 = 22.04$, df $= 5$, $P = 0.001$). Specifically, riparian nests received fewer invertebrates
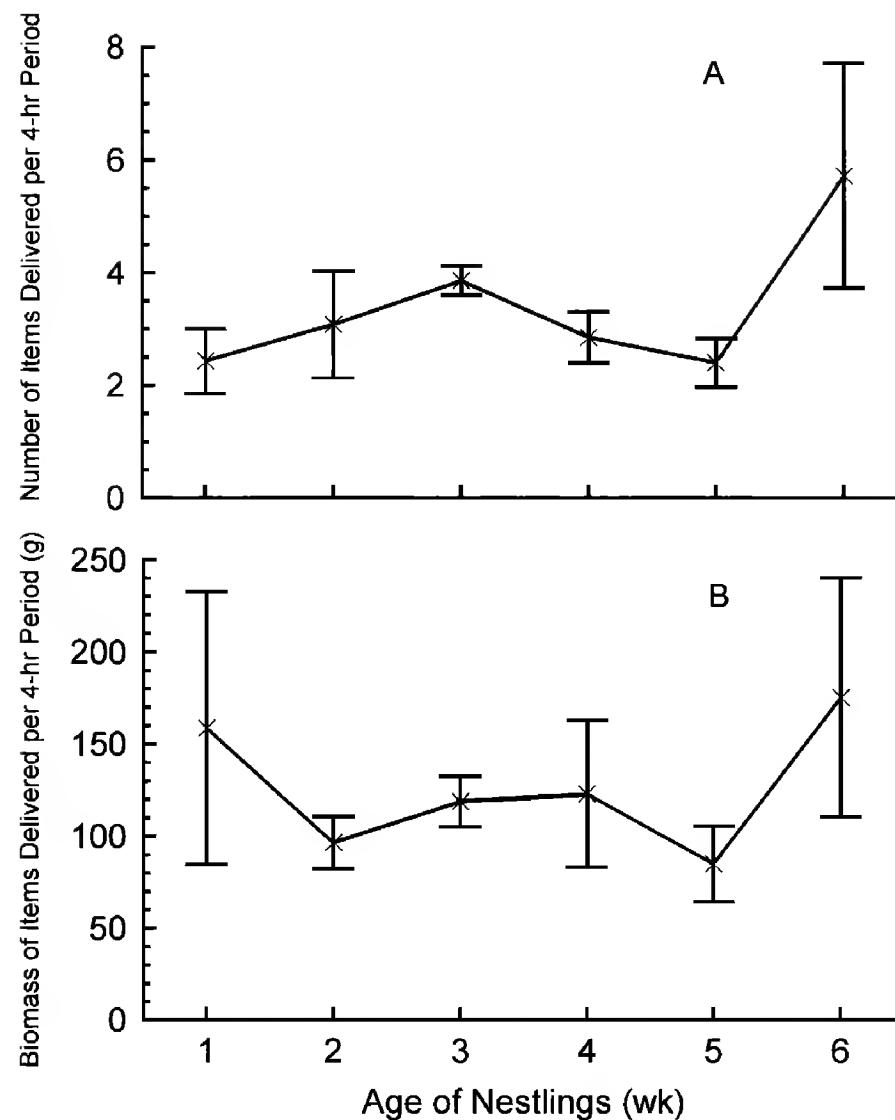
Figure 1.   Prey delivery rate to nests by adult Red-shouldered Hawks as a function of nestling age. (A) Prey delivery rate measured as the number of items delivered per 4-hr observation period. (B) Prey delivery rate measured as the estimated biomass of prey delivered per 4-hr observation period. Mean ± SE.
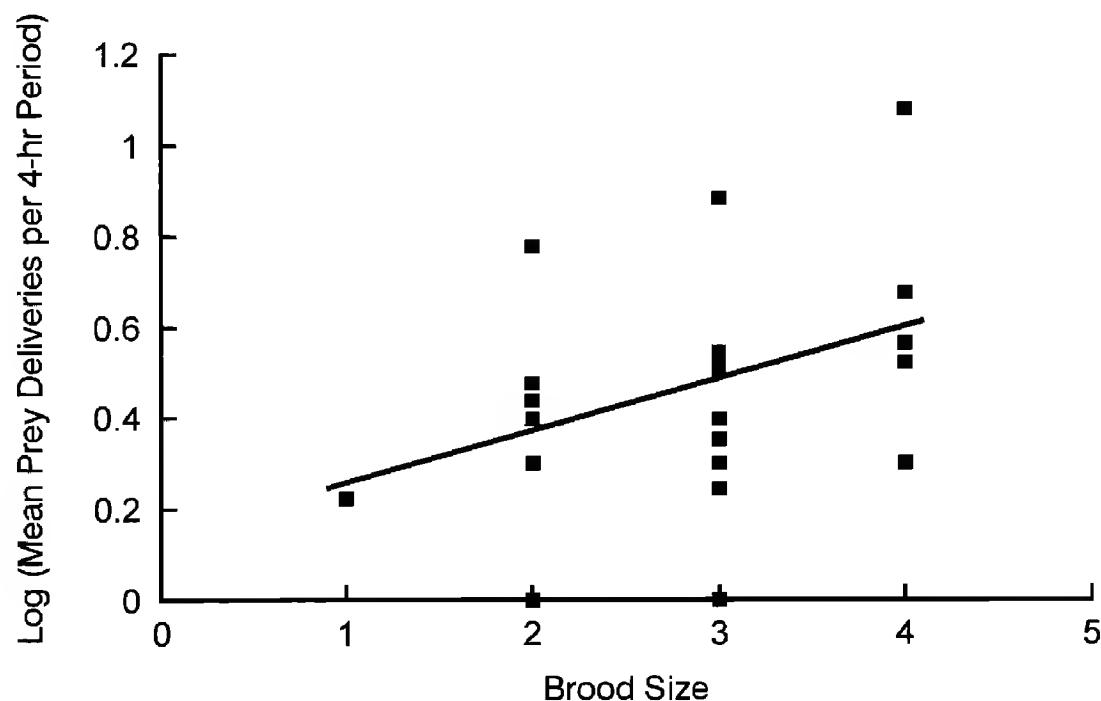
Figure 2.   Prey delivery rate by adult Red-shouldered Hawks as a function of brood size. Each point represents the mean season-long prey delivery rate for a single nest. Prey delivery rate was weakly correlated with brood size (R^2 = 0.14, one-tailed P = 0.048, but see text for details).

Table 2. Prey items delivered to Red-shouldered Hawk nests in southwestern Ohio and identified to taxonomic class or species, 1997 to 2001.

PREY TYPES	NUMBER IDENTIFIED TO SPECIES OR GENUS	NUMBER IDENTIFIED TO CLASS (%)[a]	BIOMASS OF PREY IDENTIFIED TO CLASS IN g (%)[b]
Class Mammalia		64 (31.5)	4084 (55.9)
Vole (*Microtus* spp.)	12		
Mice (*Peromyscus* spp.)	4		
Chipmunk (*Tamias striatus*)	5		
Eastern gray squirrel (*Sciurus carolinensis*)	4		
Eastern mole (*Scalopus aquaticus*)	1		
Eastern cottontail (*Sylvilagus floridanus*)	1		
Class Reptilia[c]		46 (22.7)	549 (7.5)
Garter snake (*Thamnophis sirtalis*)	4		
Class Amphibia		36 (17.7)	1731 (23.7)
Bullfrog (*Rana catesbeiana*)	4		
Other frogs (*Rana* spp.)	29		
Class Aves		14 (6.9)	506 (6.9)
Class Osteichthyes		5 (2.5)	253 (3.4)
Yellow perch (*Perca flavescens*)	1		
Class Oligochaeta[d]		32 (15.8)	160 (2.2)
Class Crustacea[e]		4 (2.0)	28 (0.4)
Class Insecta		2 (1.0)	2 (<0.1)
Total	65	203	7313

[a] Percent of 203 total prey items that were identified to class.
[b] Percent of 7313 total g of prey items that were identified to class.
[c] Prey consisted entirely of snakes.
[d] Prey consisted entirely of unidentified earthworms.
[e] Prey consisted entirely of unidentified crayfish.

than expected, based on the overall distribution of prey types.

Adult Behavior. Adult attendance at the nest was negatively related to nestling age ($R^2 = 0.96$, $P = 0.001$, $N = 6$ wk; Fig. 3A). Similarly, time adults spent brooding nestlings declined significantly as nestlings aged ($R^2 = 0.94$, $P = 0.001$, $N = 6$ wk; Fig. 3B). Time adults spent feeding nestlings also was negatively correlated with nestling age ($R^2 = 0.92$, $P = 0.002$, $N = 6$ wk; Fig. 4).

Nestling Behavior. Time nestlings spent feeding themselves was positively correlated with nestling age ($R^2 = 0.92$, $P = 0.003$, $N = 6$ wk; Fig. 4), but time nestlings spent at all feeding behaviors (being fed and feeding themselves) did not vary as nestlings grew ($R^2 = 0.07$, $P = 0.61$, $N = 6$ wk).

DISCUSSION

Prey Types. Diet of eastern Red-shouldered Hawks (*B. l. lineatus*) has been documented in sev-eral locations using either observational data or prey remains in pellets or nests (Craighead and Craighead 1956, Portnoy and Dodge 1979, Bednarz and Dinsmore 1985, others). For Red-shouldered Hawks, observational data provide a more accurate and quantitative description of diet than prey remains in pellets, due to the prevalence in the diet of highly-digestible amphibians, which frequently are under-represented in pellets or nest remains (Portnoy and Dodge 1979, Bednarz and Dinsmore 1985, Welch 1987). Diet of Red-shouldered Hawks varies widely from location to location, and from year to year at the same location (Bednarz and Dinsmore 1985), underscoring the ability of this species to adapt to available conditions. In published studies, mammals comprised 17–72% of nesting Red-shouldered Hawks' diet (by number of prey items), amphibians 12–46%, reptiles 3–24%, birds 0–8%, fish 0–3%, and inverte-
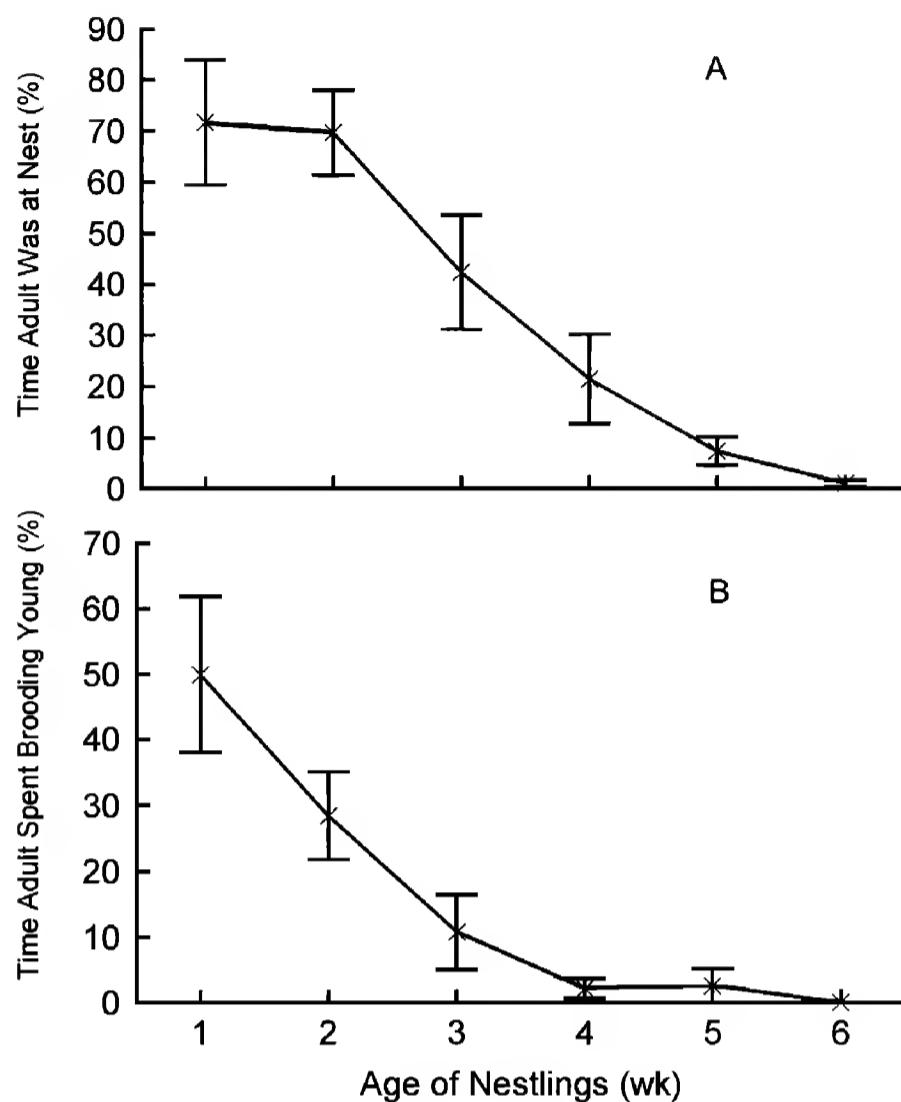
Figure 3. (A) Adult attendance at nests of Red-shouldered Hawks as a function of nestling age. Adult attendance was negatively related with nestling age ($R^2 = 0.96$, $P = 0.001$). (B) Brooding behavior of adult Red-shouldered Hawks as a function of nestling age. Time adults spent brooding nestlings declined significantly as nestlings aged ($R^2 = 0.94$, $P = 0.001$). Mean ± SE.
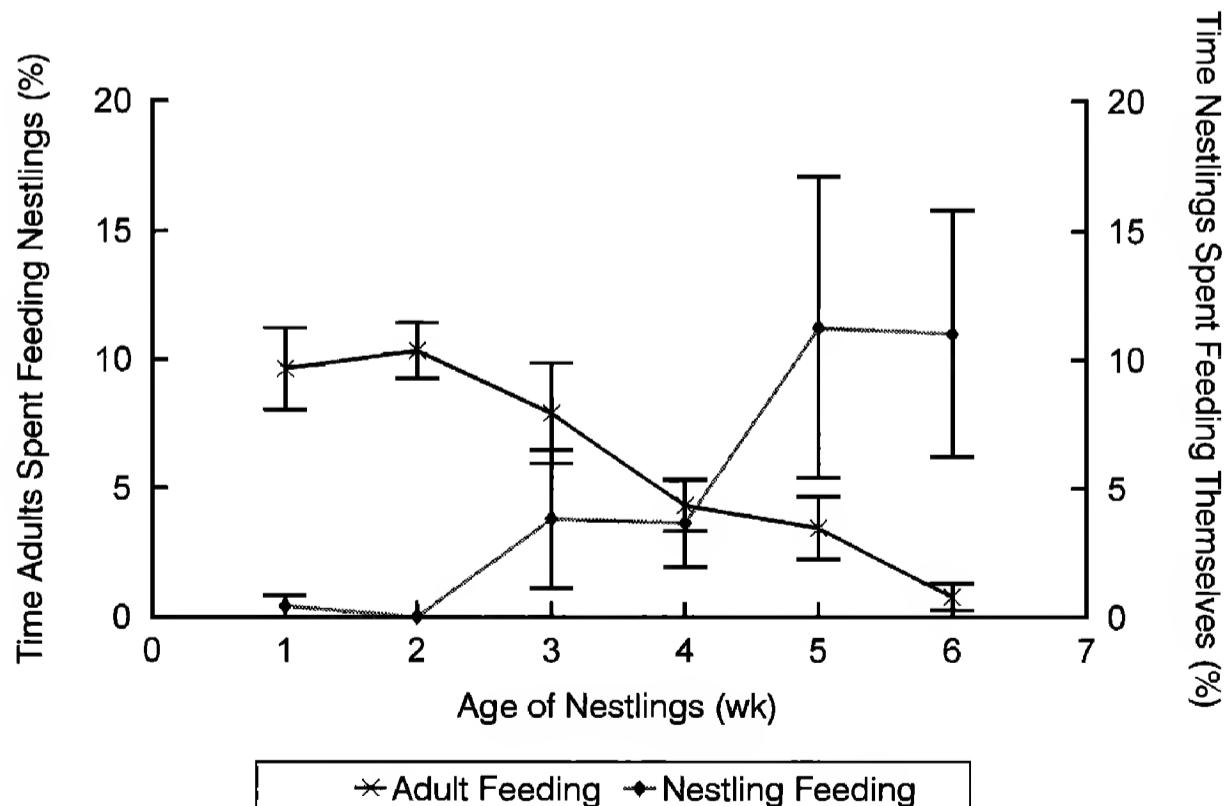

Figure 4. Feeding behavior of adult and nestling Red-shouldered Hawks as a function of nestling age. Time adults spent feeding nestlings was negatively related with nestling age ($R^2 = 0.92$, $P = 0.002$) and time nestlings spent feeding themselves was positively related with nestling age ($R^2 = 0.92$, $P = 0.003$). Mean ± SE.

brates 0–26% (observational studies only: Portnoy and Dodge 1979, Penak 1982, Bednarz and Dinsmore 1985, Parker 1986, Welch 1987, Howell and Chapman 1998, this study). The abundance of aquatic prey in the Red-shouldered Hawk diet can be as high as 60% of the diet (Howell and Chapman 1998), a factor that is likely related to the preference of this species for nesting near wetlands, ponds or streams (Woodrey 1986, Bosakowski et al. 1992, Moorman and Chapman 1996, Dykstra et al. 2000a, 2001b). The hawks we observed in southwestern Ohio delivered more mammalian prey and fewer aquatic prey items than those observed in bottomland forests further south in Missouri and Georgia (Parker 1986, Howell and Chapman 1998). This is likely due to the primarily upland nature of our study site; even birds nesting in the floodplain of the Little Miami River had access to only a narrow corridor (150–300 m) of river and bottomland forest, surrounded by slopes and upland habitats. The only difference in diet between upland sites and floodplain sites, fewer earthworms delivered at floodplain sites, was probably due to the paucity of suburban development within the floodplain itself. We observed that earthworms were delivered in rapid succession (10 worms in 61 min at one nest, 10 worms in 70 min at another nest) at nest sites in lawns or adjacent to lawns, following a rain.

Prey species observed and identified were generally similar to those reported in other studies of Red-shouldered Hawks, consisting primarily of voles and mice, garter and other snakes, and *Rana* frogs, with a few exceptions. On one occasion, an adult delivered a small nest containing two unidentified passerine nestlings, which were removed individually from the nest materials and eaten by a nestling; delivery of nests containing nestlings has been reported for Swallow-tailed Kites (*Elanoides forficatus*; Coulson 2001), but not for Red-shouldered Hawks, to our knowledge. Unusual prey species found as prey or prey remains in nests (visited in a related study) included Eastern Screech-Owl (*Otus asio*) and southern flying squirrel (*Glaucomys volans*). We also observed Red-shouldered Hawks feeding on an unidentified road kill within the study area, and on the carcass of a deer (*Odocoileus virginianus*) lying beside a road in the Hocking Hills region of south-central Ohio, about 180 km east of Cincinnati.

Prey Delivery Rate. It was unclear whether Red-shouldered Hawk food delivery rates increased with increasing brood size in this study. Although the number of prey deliveries per 4-hr was weakly correlated with brood size, the estimated biomass of those deliveries was not. These data should be interpreted with caution, because our study design was such that each nest was observed for a limited amount of time (3–4 4-hr periods at most nests; Table 1), so the mean (season-long) prey delivery rate at each nest had a fair amount of variance.

The mean 4-hr prey delivery rate for all Red-shouldered Hawk nests, 3.4 prey items per 4-hr or 116 g biomass per 4-hr, was somewhat higher than that measured in 220 hr of observation at eight nests in southwestern Quebec, 2.5 items per 4-hr or 91.1 g per 4-hr for broods of 1–4 nestlings (Penak 1982). However, hawks in southwestern Quebec were nesting at the northern limit of their range and had low nesting success (only 13% of the pairs observed fledged all the young that hatched; Penak 1982), so it is possible that these feeding rates were suboptimal.

The 4-hr prey delivery rates we documented also may be used to estimate prey delivery rates/d (14–15 hr daylight). Because we detected no difference between morning and afternoon delivery rates, the mean 4-hr rate is likely representative of all hours we observed, 0700–1800 H. However, prey delivery rates were likely lower in very early morning and in the evening (Portnoy and Dodge 1979), so we estimated that daily prey delivery rates were approximately three times our measured 4-hr rates, or 10.2 items per d and 348 g biomass/d. This was slightly higher than rates measured at two California nests each containing two nestlings, 19.6 g/hr or about 294 g/d (Snyder and Wiley 1976). As a caveat, we note that we were unable to identify or even classify to size a small number (10%) of the prey deliveries we observed, so our estimation of prey biomass was not exact and may be biased in some way.

Prey delivery rate to nestlings may be an indicator of the adequacy of the prey base (Newton 1979), an important component of habitat quality for raptors. Individual raptors or populations of raptors living in marginal habitat with low prey availability may have lower prey delivery rates to their nestlings, which can result in nestling mortality and, hence, lower adult productivity (Dykstra et al. 1998). Lower prey delivery rates also may result from aberrant parental behavior due to contamination of the adults by toxins, such as organochlorines (Fox et al. 1978, McArthur et al. 1983,

Kubiak et al. 1989). Thus, lower prey delivery rates may be an early indicator of subtle problems in a population or its environment.

However, it is important to have baseline information on prey delivery rates from a productive population in order to make any assessments of other populations. In the absence of other data, nesting behaviors alone cannot indicate whether a population is viable, but we have investigated several other aspects of the ecology of Red-shouldered Hawks in southwestern Ohio. Despite their somewhat atypical suburban habitat, the population does not appear to be compromised in any way that we have measured. Compared to more rural populations in south-central Ohio and elsewhere, the suburban birds reproduce at relatively high, consistent rates (Dykstra et al. 2000a, 2000b), nest at a high nest density (Dykstra et al. 2000a), choose suitable nest sites similar to those in rural areas (Dykstra et al. 2000a), and inhabit home ranges that are typical in size for Red-shouldered Hawks, although they are less forested than those measured elsewhere (Howell and Chapman 1997, Dykstra et al. 2001a). Unfortunately, we have only limited data on some aspects of population dynamics such as post-fledging survival and long-term population stability. Preliminary analysis of post-fledging survival using banding data indicated that about 50% of the fledglings survived the first year (C. Dykstra, J. Hays, and M. Simon, unpubl. data), which was similar to the survival rate determined by Henny (1972) using banding data. However, in the long term, the population may be decreasing; anecdotal data suggest that the suburban birds of southwestern Ohio may have lost nesting habitat in the past 20–30 yr, as urbanization has proceeded (Dykstra et al. 2000a). Thus, with the exception of long-term population stability, which is unknown, most evidence suggests that the Red-shouldered Hawks in the southwestern Ohio study area probably comprise a productive population inhabiting a suitable environment at this time and, hence, data from this population may serve as a baseline for evaluating prey delivery rates and nesting behaviors of other populations throughout the Midwest and elsewhere.

Other Behaviors. The nestling period of Red-shouldered Hawks may be divided into three distinct behavioral stages (Newton 1979), as evidenced by our behavior data (Figs. 3 and 4). In the early nestling stage, wk 1 and 2 after hatch, adults were present in the nest ca. 70% of the day, and

much of that time was spent brooding, particularly in wk 1. Nestlings were inactive, and unable to feed themselves; feeding was done by the adults and comprised about 10% of the day. In the middle nestling stage, wk 3 and 4 after hatch, behaviors were transitional. Adult attendance declined rapidly, as did brooding, which had nearly ceased by wk 4. There was no change in the overall amount of time spent feeding, but the time adults fed nestlings declined to 4–8% of the day, and nestlings fed themselves for 4% of the day. In the late nestling stage, wk 5 and 6 after hatch, brooding had ceased and adults were present in the nest primarily to deliver food. Nestlings were active and fed themselves most of the time, on average about 11% of the day.

Behaviors measured in our study were quite similar to those documented in central Massachusetts using a time-lapse movie camera in 1974. In that study, adult attendance rates were >80% in wk 1, then declined rapidly to <5% by the end of wk 3 (Portnoy and Dodge 1979); this was consistent with our study except that southwestern Ohio birds still attended the nest 42% of the day during wk 3 and 21% during wk 4.

Time adults spent feeding nestlings and nestlings spent feeding themselves in the Massachusetts study also were similar to those recorded in this study. In wk 1 and 2, adults fed chicks for ca. 7% of the day (estimated from graphical data, Portnoy and Dodge 1979), compared to 10% of the day in southwestern Ohio. In wk 3 and 4, Massachusetts nestlings fed themselves for about 6% of the day while adults fed them for only 4% of the day (Portnoy and Dodge 1979), compared to 4% for self-feeding and 6% for adult-feeding in southwestern Ohio. In wk 5 and 6, nestlings at both locations fed themselves for about 11% of the day (Portnoy and Dodge 1979, this study). It is not known whether the slightly higher rates of adult attendance and adult-feeding in wk 3 and 4 recorded in southwestern Ohio were statistically significantly different from those in Massachusetts, or, if so, whether they represent real behavioral differences or are artifacts caused by differences in study designs (e.g., camera vs. direct observation, number of hours and times of day recorded).

Summary. Aberrant food delivery rates or other nesting behaviors may be an early indicator of subtle problems in a raptor population or its environment. Measurements of prey delivery rates and nesting behaviors, as well as measurements of pro-

ductivity, can be used to compare data from marginal populations to benchmark data from a healthy population. We measured prey delivery rates and other nesting behaviors in an apparently productive population of suburban Red-shouldered Hawks inhabiting a suitable environment in southwestern Ohio. These data may serve as a baseline for evaluating behaviors of other populations throughout the Midwest and elsewhere, particularly where the Red-shouldered Hawk is classified as a species of special concern because of habitat loss.

LITERATURE CITED

BEDNARZ, J.C. AND J.J. DINSMORE. 1985. Flexible dietary response and feeding ecology of the Red-shouldered Hawk, *Buteo lineatus*, in Iowa. *Can. Field-Nat.* 99:262–264.

BOSAKOWSKI, T., D.G. SMITH, AND R. SPEISER. 1992. Status, nesting density, and macrohabitat selection of Red-shouldered Hawks in northern New Jersey. *Wilson Bull.* 104:434–446.

BYERS, C.R., R.K. STEINHORST, AND P.R. KRAUSMAN. 1984. Clarification of a technique for analysis of utilization-availability data. *J. Wildl. Manage.* 48:1050–1053.

CASTRALE, J.S. 1991. Eastern woodland buteos. Pages 50–59 *in* B.G. Pendleton, D.L. Krahe, M.N. LeFranc, Jr., K. Titus, J.C. Bednarz, D.E. Andersen, and B.A. Millsap [EDS.], Proceedings of the Midwest Raptor Management Symposium and Workshop. Natl. Wildl. Fed., Washington, DC U.S.A.

COLLOPY, M.W. 1984. Parental care and feeding ecology of Golden Eagle nestlings. *Auk* 101:753–760.

COULSON, J.O. 2001. Swallow-tailed Kites carry nests containing passerine nestlings to their own nests. *Wilson Bull.* 113:340–342.

CRAIGHEAD, J.J. AND F.C. CRAIGHEAD, JR. 1956. Hawks, owls, and wildlife. Stackpole Co., Harrisburg, PA and Wildlife Management Institute, Washington, DC U.S.A.

DYKSTRA, C.R. 1995. Effects of contaminants, food availability, and weather on the reproductive rate of Lake Superior Bald Eagles (*Haliaeetus leucocephalus*). Ph.D dissertation, University of Wisconsin-Madison, Madison, WI U.S.A.

———, M.W. MEYER, D.K. WARNKE, W.H. KARASOV, D.E. ANDERSEN, W.W. BOWERMAN, IV, AND J.P. GIESY. 1998. Low reproductive rates of Lake Superior Bald Eagles: low food delivery rates or environmental contaminants? *J. Great Lakes Res.* 24:32–44.

———, J.L. HAYS, F.B. DANIEL, AND M.M. SIMON. 2000a. Nest site selection and productivity of suburban Red-shouldered Hawks in southern Ohio. *Condor* 102:401–408.

———, ———, ———, AND ———. 2000b. Breeding biology of suburban Red-shouldered Hawks in southern Ohio. *Ohio Birds Nat. Hist.* 1:137–144.

———, ———, ———, AND ———. 2001a. Home range and habitat use of suburban Red-shouldered Hawks in southwestern Ohio. *Wilson Bull.* 113:308–316.

———, F.B. DANIEL, J.L. HAYS, AND M.M. SIMON. 2001b Correlation of Red-shouldered Hawk abundance and macrohabitat characteristics in southern Ohio. *Condor* 103:652–656.

FOX, G.A., A.P. GILMAN, D.R. PEAKALL, AND F.W. ANDERKA 1978. Behavioral abnormalities of nesting Lake Ontario herring gulls. *J. Wildl. Manage.* 42:477–483.

HAYS, J.L. 2000. Red-shouldered Hawks nesting on human-made structures in southwest Ohio. Pages 469–471 *in* R.D. Chancellor and B.-U. Meyburg [EDS.], Raptors at risk: Proceedings of the V World Conference on Birds of Prey and Owls. WWGBP, Berlin, Germany and Hancock House Publishers, Surrey, BC Canada.

HENNY, C.J. 1972. Analysis of population dynamics of selected avian species with special reference to changes during the modern pesticide era. U.S. Bureau of Sport Fisheries and Wildlife (Wildl. Res. Rep. No. 1) Washington, DC U.S.A.

HILES, R. AND F.W. JONES. 1941. Age, growth, and production of the yellow perch, *Perca flavescens* (Mitchill) of Saginaw Bay. *Trans. Am. Fish. Soc.* 70:102–122.

HOWELL, D.L. AND B.R. CHAPMAN. 1997. Home range and habitat use of Red-shouldered Hawks in Georgia. *Wilson Bull.* 109:131–44.

——— AND ———. 1998. Prey brought to Red-shouldered Hawk nests in the Georgia Piedmont. *J. Raptor Res.* 32:257–260.

JAYNE, B.C. AND A.F. BENNETT. 1990. Scaling of speed and endurance in garter snakes: a comparison of cross-sectional and longitudinal allometries. *J. Zool. Lond.* 220:257–277.

KUBIAK, T.J., H.J. HARRIS, L.M. SMITH, T.R. SCHWARTZ, D.L. STALLING, J.A. TRICK, L. SILEO, D.E. DOCHERTY, AND T.C. ERDMAN. 1989. Microcontaminants and reproductive impairment of the Forster's Tern on Green Bay, Lake Michigan—1983. *Arch. Environ. Contam. Tox.* 18:706–727.

McArthur, M.L.B., G.A. Fox, D.B. Peakall, and B.J.R. Philogene. 1983. Ecological significance of behavioral and hormonal abnormalities in breeding ring doves fed an organochlorine chemical mixture. *Arch. Environ. Contam. Tox.* 12:343–353.

Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. *Am. Midl. Nat.* 37: 223–249.

Moorman, C.E. and B.R. Chapman. 1996. Nest-site selection of Red-shouldered and Red-tailed Hawks in a managed forest. *Wilson Bull.* 108:357–358.

Neu, C.W., C.R. Byers, and J.M. Peek. 1974. A technique for the analysis of utilization-availability data. *J. Wildl. Manage.* 38:541–545.

Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, SD U.S.A.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. *Ann. Assoc. Am. Geographers* 77:118–125.

Parker, M.A. 1986. The foraging behavior and habitat use of breeding Red-shouldered Hawks in southeastern Missouri. M.S. thesis, University of Missouri-Columbia, Columbia, MO U.S.A.

Penak, B.L. 1982. Aspects of the nutritional ecology of the Red-shouldered Hawk (*Buteo lineatus lineatus*) in southwestern Quebec. M.S. thesis, McGill University, Ste.-Anne-de-Bellevue, Quebec, Canada.

Portnoy, J.W. and W.E. Dodge. 1979. Red-shouldered Hawk nesting ecology and behavior. *Wilson Bull.* 91. 104–117.

Sibley, D.A. 2000. The Sibly guide to birds. National Audubon Society and Alfred A. Knopf, Inc., New York

Snyder, N.F.R. and J.W. Wiley. 1976. Sexual size dimorphism in hawks and owls of North America. Ornithol Monogr. No. 20. American Ornithologists' Union and Allen Press, Inc., Lawrence, KS U.S.A.

Steenhof, K. 1983. Prey weights for computing percent biomass in raptor diets. *Raptor Res.* 17:15–27.

Titus, K., M.R. Fuller, D.F. Stauffer, and J.R. Sauer 1989. Pages 53–64 in B.G. Pendleton, M.N. LeFranc, Jr., and M.B. Moss [Eds.], Buteos. Proceedings of the Northeastern Raptor Management Symposium and Workshop. Natl. Wildl. Fed., Washington, DC U.S.A.

Welch, R.J. 1987. Food habits of the Red-shouldered Hawk in Wisconsin. *Passenger Pigeon* 49:81–92.

Wilkinson, L. 1988. Systat: the system for statistics. Systat, Inc., Evanston, IL U.S.A.

Woodrey, M.S. 1986. Characteristics of Red-shouldered Hawk nests in southeast Ohio. *Wilson Bull.* 98:466–469.

RED-SHOULDERED HAWK (*BUTEO LINEATUS*) ABUNDANCE AND HABITAT IN A RECLAIMED MINE LANDSCAPE

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Abstract.—Fragmentation of the landscape by large-scale mining may affect Red-shouldered Hawk (*Buteo lineatus*) populations by reducing the amount of forested habitat available in a landscape and by creating fragmented forest patches surrounded by reclaimed mine lands. We examined habitat characteristics and relative abundance of Red-shouldered Hawks in reclaimed mine landscapes within four treatments: early-successional grassland habitat, mid-successional shrub/pole habitat, late-successional fragmented forest habitat, and late-successional intact forest habitat. We quantified microhabitat characteristics within an 11.3-m-radius plot centered on 156 vegetation plots throughout the four treatments. We surveyed 48 stations on and adjacent to three mines for Red-shouldered Hawks using standardized broadcast call techniques during February 2000–January 2001 and measured landscape characteristics within 1000-m buffer zones centered on each station from digitized aerial photographs. Mean abundance of Red-shouldered Hawks was significantly higher in the intact forest ($\bar{x}$ = 0.07 detections/point, SE = 0.03) than the grassland ($\bar{x}$ = 0.01, SE = 0.01) treatment, but did not differ from the fragmented forest ($\bar{x}$ = 0.03, SE = 0.01) or shrub/pole ($\bar{x}$ = 0.03, SE = 0.01) treatments. Most microhabitat characteristics in both fragmented and intact forest differed from shrub/pole and grasslands. Amount of wetland was the most important characteristic determining presence of Red-shouldered Hawks in a forest-dominated landscape. More wetlands in the landscape may provide abundant amphibians and reptiles, which are important in the diet of Red-shouldered Hawks.

Key Words: *Buteo lineatus*; *Red-shouldered Hawk*; *habitat use*; *landscape*; *microhabitat*; *mining*.

ABUNDANCIA Y HABITAT DEL GAVILAN DE HOMBROS ROJOS (*BUTEO LINEATUS*) EN UN PAISAJE DE MINERIA RESTAURADO

Resumen.—La fragmentación del paisaje por la minería a gran escala puede afectar a las poblaciones del gavilán de hombros rojos (*Buteo lineatus*) mediante la reduccion de la cantidad de hábitat de bosque disponible en un paisaje, creando parches de bosque fragmentado rodeados por tierras de minería restauradas. Examinamos las características del hábitat y la abundancia relativa del halcón de hombros rojos en paisajes de minería restaurados, con cuatro tratamientos: hábitat de pradera de sucesión temprana, hábitat de arbustos de sucesión media, hábitat de bosque fragmentado de sucesión tardío, y hábitat de bosque intacto de sucesión tardío. Cuantificamos las características micro hábitat en una parcela de 11.3 m de radio, en 156 cuadrantes de vegetación con los cuatro tratamientos. Inspeccionamos 48 estaciones para el gavilán de hombros rojos dentro y en sitios adyacentes a tres minas, utilizando técnicas de emisión de vocalizaciones estandardizadas durante febrero del 2000–enero 2001. Se midieron las características del paisaje dentro de zonas de amortiguación de 1000 m centradas en cada estación determinada a partir de fotografías aéreas digitalizadas. La abundancia media del gavilán de hombros rojos fue apreciablemente más alta en el bosque intacto ($\bar{x}$ = 0.07 detección/ punto, SE = 0.03) que en el tratamiento de la pradera ($\bar{x}$ = 0.01, SE = 0.01), pero no difirió de los tratamientos de bosque fragmentados ($\bar{x}$ = 0.03, SE = 0.01) ni del de arbustos ($\bar{x}$ = 0.03, SE = 0.01). La mayoría de las características de los micro hábitat en bosques fragmentados e intactos difirieron de los de arbustos y praderas. La existencia de humedales fue la característica más importante para determinar la presencia de gavilanes de hombros rojos en un paisaje dominado por bosque. El aumento de humedales en el paisaje podría proporcionar mayor abundancia de anfibios y reptiles, los cuales son muy importantes en la dieta del gavilán de hombros rojos.

[Traducción de César Márquez]

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The eastern subspecies of the Red-shouldered Hawk (*Buteo lineatus lineatus*) is considered primarily a forest species that breeds in large tracts of contiguous, mature forest (Hall 1983, Buckelew and Hall 1994, Crocoll 1994), although some populations thrive in suburban landscapes (Dykstra et al. 2001). Although quantitative data are lacking, trends suggest a long-term decline in the numbers of Red-shouldered Hawks in several northern states, including New Jersey, Illinois, Iowa, New York, Michigan, and Wisconsin (Peterson and Crocoll 1992, Crocoll 1994). A number of states attributed the decline primarily to reduction of closed canopy forest due to logging, agriculture, urban development, and drainage of wooded wetlands; and secondarily to competition with Red-tailed Hawks (*Buteo jamaicensis*) (Peterson and Crocoll 1992). Red-shouldered Hawk populations in West Virginia appear stable (Sauer et al. 2001) with confirmed breeding in 34 out of 455 Breeding Bird Survey blocks and probable or possible breeding in 123 blocks (Buckelew and Hall 1994).

Nest-site selection studies of Red-shouldered Hawks have concluded that they select large, mature stands of deciduous trees that have a well developed canopy layer and reduced understory e.g., (Portnoy and Dodge 1979, Titus and Mosher 1981, Bednarz and Dinsmore 1982, Morris and Lemon 1983, Bloom et al. 1993). Nest sites also have been associated with floodplain forest near areas of open water (Bent 1937, Titus and Mosher 1981, Bednarz and Dinsmore 1981, 1982, Moorman and Chapman 1996). Other studies have shown Red-shouldered Hawks to nest in upland, hardwood forests rather than floodplain forest, but still in close proximity to water (Crocoll and Parker 1989, Belleman 1998). Bednarz and Dinsmore (1982) found that Red-shouldered Hawks in Iowa used upland forest habitat immediately adjacent to floodplains, and they suggested that this adjacent upland forest may be used when floodplain forest is limited in area.

No previous studies have examined the effect of mountaintop mining on Red-shouldered Hawks, although the loss and fragmentation of forest and creation of edge by the mountaintop mining process may have negative effects on this species. Clearing of forests and creation of fragmented forest patches surrounded by reclaimed grassland may decrease the suitability of mountaintop mined areas and lead to lower abundance of forest raptor populations that occupy and breed in large blocks of intact forest. In a study on 12 reclaimed surface mines in northern West Virginia and southern Pennsylvania, Mindell (1978) noted that although American Kestrels (*Falco sparverius*) and Red-tailed Hawks were relatively common, other raptor species such as Red-shouldered Hawks were much less common. On reclaimed surface mines in northern West Virginia, Forren (1981) found no Red-shouldered Hawks using artificial perches and made no mention of their presence on the surface mine at any time. In these studies, reclaimed mines were approximately 0.7–40 ha in size, while mountaintop mines typically are much larger and encompass hundreds to thousands of hectares. Creation of edge also may increase competition between Red-shouldered Hawks and Red-tailed Hawks for nesting areas, because forest fragmentation and large open areas favor the latter species (Bednarz and Dinsmore 1982, Preston and Beane 1993, Moorman and Chapman 1996). To assess the impact of these relatively large-scale mountaintop mines on a forest raptor, we quantified relative abundance of Red-shouldered Hawks and examined landscape characteristics important to this species in southern West Virginia.

STUDY AREA

We quantified Red-shouldered Hawk relative abundance and habitat characteristics at three mountaintop mines in the southern West Virginia counties of Boone, Logan, Kanawha, and Fayette. Reclaimed areas at each mine encompassed 2431 ha, 2180 ha, and 1819 ha. Study areas were divided into four treatments: intact forest, fragmented forest, young reclaimed mine (grassland), and older reclaimed mine (shrub/pole). The intact forest treatment included mature forest on ridgetops, midslopes, and along first and second order streams and was located adjacent to the mines and within the same river drainage basin, but was undisturbed by mining activities. The fragmented forest treatment included mature forest on midslopes and along first and second order streams that were almost entirely surrounded by reclaimed mine land. Grassland areas, estimated to be 5–19 yr of age, consisted primarily of grasses and scattered shrubs Shrub/pole areas were made up of shrub and pole-sized vegetation and ranged from 13–27 yr of age. Lack of succession on some older grassland sites resulted in an overlap in age for the latter two treatments. Wetlands were scattered throughout the grassland and shrub/pole treatments, the majority were "fill" ponds located at the bottom of reclaimed hillsides to collect sediment due to erosion. The fragmented forest treatment also contained fill ponds that were located at the bottom of reclaimed grassland hillsides adjoining the forest patch.

The intact and fragmented forest areas were comprised of mature Appalachian hardwood species typical of mixed mesophytic forest (Strausbaugh and Core

1977). Common species included red and white oak (*Quercus rubra* and *Q. alba*), pignut and shagbark hickory (*Carya glabra* and *C. ovata*), yellow poplar (*Liriodendron tulipifera*), and American beech (*Fagus grandifolia*). Primary vegetation on grassland areas was tall fescue (*Festuca arundinacea*), sericea (*Lespedeza cuneata*), and autumn olive (*Elaeagnus umbellata*); but also included multiflora rose (*Rosa multiflora*), legumes such as birdsfoot trefoil (*Lotus corniculatus*) and purple vetch (*Vicia americana*), and occasionally patches of planted wheat (*Triticum aestivum* L.). There were two distinct shrub/pole treatments. The first type consisted mostly of black locust (*Robinia pseudoacacia*), European black alder (*Alnus glutinosa*), and *Rubus* species. The second type included primarily coniferous species such as red pine (*Pinus resinosa*), Scotch pine (*P. sylvestris*), and pitch pine (*P. rigida*).

METHODS

We quantified Red-shouldered Hawk presence and relative abundance at 48 sampling points located in 14 stream drainages with 1–6 points within each drainage. Each of the 14 stream drainages were ≥1000 m apart. Within a drainage, points were spaced approximately 350–1320 m ($\bar{x}$ = 733 m) apart. Because there were no instances of a Red-shouldered Hawk being detected multiple times among the points <800 m apart, we believe that lack of independence between sample points did not influence our data. Sample points were divided equally among the four treatment types with 12 points in each treatment. Because one mine lacked the shrub/pole habitat, the number of sample points at each of the three mines (19, 18, and 12) varied slightly. All 48 points were sampled monthly (February 2000–January 2001) over a 4–6-d period with at least three treatments sampled on a given day to minimize temporal variability between treatments. A set of points representing at least three treatment types for each mine was assigned to be surveyed on a given day. The original order that those points were sampled was randomly established during the first survey. In subsequent surveys, the order in which points were sampled was systematically varied throughout the sampling day.

Broadcasting conspecific vocalizations has been shown to be an effective way to survey targeted raptor species (Rosenfield et al. 1988, Mosher et al. 1990, Kennedy and Stahlecker 1993). During winter months, we conducted broadcast surveys from one-half hr after sunrise until 1600 H because raptors can be active throughout the day during cooler weather. During summer months, we conducted surveys from one-half hr after sunrise until 1300 H, because shifts in raptor activity in the afternoon may reduce the detectability of certain raptor species such as Red-tailed Hawks and *Accipiters* (Bunn et al. 1995). Two observers trained in identification of raptors by sight and sound were present at every survey. During the survey period, both observers simultaneously watched and listened for raptors. Data recorded included latency (time from start of survey until first raptor detection), raptor species detected, age and sex (if possible), behavior during detection (perch and call, flyby and call, silent perch, silent flyby, vocal only), time each individual bird was seen, estimated distance bird was from observer, and treatment in which a bird was first detected. Surveys were

not conducted in inclement weather (moderate to heavy rain, fog, or wind).

Broadcast surveys lasted 10 min and were based on the Fuller and Mosher (1987) protocol. We used a TOA Transistor® megaphone speaker[2] (Frederick Goertz Ltd., Victoria, BC) with an attached CD player for broadcasting calls. One observer held the speaker 1.5 m above the ground and rotated 120° between each broadcast. Broadcast call volume was adjusted between 100–110 db at 1 m from the speaker. Using the same broadcast volume, Mosher et al. (1990) estimated that calls could be heard ca. 0.75 km from the speaker. Before and after leaf-out, mean decibel readings at 50 m from the speaker were similar between the four treatments (Balcerzak 2001). Vocalizations alternated between Great-horned Owl (*Bubo virginianus*) and Red-shouldered Hawk calls during broadcasting. Both calls were recorded from the Peterson Field Guide to Bird Songs of Eastern and Central North America CD (Peterson Field Guide Series 1990). Mosher and Fuller (1996) found that Great-horned Owl vocalizations were able to elicit responses from a variety of raptor species on a single survey. McLeod and Andersen (1998) compared conspecific and Great-horned Owl calls in attracting Red-shouldered Hawks and found that Red-shouldered Hawks responded to Great-horned Owl vocalizations, although response rates were higher for conspecific vocalizations earlier in the season and in the day. Therefore, we used both calls within a survey period to maximize detection of a number of raptor species (Balcerzak 2001) as well as specifically target Red-shouldered Hawks. We randomly selected one call to start the first survey each day. We then alternated the starting call throughout the entire daily session.

For landscape-level habitat analysis, each survey point was geographically referenced using a global positioning system (GPS) receiver. Using a Geographic Information System (GIS), we determined landcover from U.S. Geological Survey (USGS) Digital Orthophoto Quadrangle (DOQ) images within 1000-m radius buffer zones placed around each broadcast station. The 1000-m radius (3.14 km², 314 ha) zone was based on the maximum home range size for Red-shouldered Hawks (Bednarz and Dinsmore 1981, Crocoll 1994). Although there was some overlap between the 1000-m buffer zones around broadcast points within a stream drainage, we completed landscape analyses for each individual point because we felt it would better reflect the habitat available to a bird detected at a given point. We classified landcover within the buffer zones into nine types: early-successional grassland habitat, mid-successional shrub/pole habitat (coniferous and deciduous), late-successional forest habitat (coniferous and deciduous), development, roads/bare ground, open water, and wetland. The ESRI® ArcView extension Patch Analyst 2.2 (ESRI, Redlands, CA) was used to analyze habitat composition of the 1000 m buffer zone and to calculate estimated values for 19 landscape variables (Table 1).

We summarized vegetation data collected at 156 points spaced ≥250 m apart within the 14 stream drainages into

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[2] Use of tradenames does not imply endorsement by the Federal Government.

Table 1.   Abbreviations and descriptions of 19 variables used in landscape analyses of habitat use of Red-shouldered Hawks in southern West Virginia during February 2000–January 2001.

ABBREVIATION	DESCRIPTION
DEVELOPMENT	Amount of human development (in ha). Includes residential and commercial buildings.
EARLY-SUCC. GRASS	Amount of early successional habitat (in ha). Consists of mostly grasslands and scattered shrubs.
LATE-SUCC. CONIFER	Amount of late successional habitat (in ha). Consists of mature, coniferous forest, mostly Eastern hemlock (*Tsuga canadensis*).
LATE-SUCC. DECIDUOUS	Amount of late successional habitat (in ha). Consists of mature, deciduous forest, mostly northern red oak (*Quercus rubra*), white oak (*Q. alba*), yellow poplar (*Liriodendron tulipifera*), and American beech (*Fagus grandifolia*).
MID-SUCC. CONIFER	Amount of mid-successional habitat (in ha). Consists of coniferous shrub/pole, mostly red pine (*Pinus resinosa*), Scotch pine (*P. sylvestris*), and pitch pine (*P. rigida*).
MID-SUCC. DECIDUOUS	Amount of mid-successional habitat (in ha). Consists of deciduous shrub/pole, mostly black locust (*Robinia pseudoacacia*), European black alder (*Alnus glutinosa*), and *Rubus* species.
ROAD	Amount of primary/secondary roads and bare ground (in ha). Includes all paved and most gravel/dirt roads and any area without vegetation.
WATER	Amount of open water (in ha). Includes all streams, rivers, lakes, and ponds.
WETLAND	Amount of emergent palustrine wetland (in ha).
FOREST	Amount of total mature forest (in ha). LATE-SUCC. CONIFER and LATE-SUCC. DECIDUOUS combined.
No. FOREST PATCHES	Number of total FOREST patches.
FOREST PATCH SIZE	Mean patch size of FOREST.
CORE AREA	Total core area of FOREST in the landscape (100-m buffer used).
CORE PATCH SIZE	Mean patch size of total core area of FOREST in the landscape.
EDGE DENSITY	Edge density. Measure of amount of edge relative to the landscape area.
DIVERSITY INDEX	Shannon's Diversity Index. Measure of relative patch diversity in the landscape.
EVENNESS INDEX	Shannon's Evenness Index. Measure of patch distribution and abundance in the landscape.
DISTANCE TO WATER	Distance to nearest WATER or WETLAND (in m).
DISTANCE TO TREATMENT	Distance to next habitat/treatment type (in m).

23 variables for use in microhabitat analyses (Table 2). Four vegetation subplots of 11.3-m radius (0.04 ha) were sampled per point with one subplot centered on the point and three subplots ca. 35 m away from the center spaced 120° apart (0°, 120°, and 240°). We recorded tree species and tree diameter at breast height (DBH) >8 cm within each 11.3-m-radius subplot. Within a 5-m radius centered on each subplot, we counted shrubs, saplings, and poles taller than 0.5 m and with DBH ≤8 cm. We measured six categories of ground cover and six categories of canopy cover using a "hit or miss" method with an ocular sighting tube at five points along four 11.3-m transects that radiated north, south, east, and west from the center of the vegetation subplot (James and Shugart 1970). Canopy cover height classes were visually estimated. For each subplot, canopy height and slope were measured with a clinometer, aspect was measured with a compass, and elevation was derived with a GPS receiver.

We used analysis of variance (ANOVA) to compare mean abundance of Red-shouldered Hawks among treat-

ments. Mean abundance was calculated as the mean number of detections per point per month across all treatments. In the ANOVA model, mean abundance was the dependent variable, while treatment, season, and the interaction between treatment and season were independent variables. We defined three seasons: winter (December–March), summer (April–July), and migration (August–November). We also used ANOVA to compare microhabitat characteristics across treatments. The ANOVA models included the microhabitat variables as the dependent variable; independent variables were treatment, mine, and the interaction between treatment and mine. When differences between treatments were detected by ANOVA, we used the Waller-Duncan K-ratio t test to determine where those differences occurred.

We used Student's t-tests to compare mean values of landscape variables between points with and without Red-shouldered Hawk detections. We also used stepwise logistic regression to identify landscape characteristics important to presence of Red-shouldered Hawks. Similar to

Table 2.   Abbreviations and descriptions of 23 microhabitat variables compared across treatments in southern West Virginia during February 2000–January 2001.

ABBREVIATION	DESCRIPTION
ASPECT	Aspect (degrees) taken at the center of plot.
SLOPE	Slope (degrees) taken at the center of plot.
ELEVATION	Elevation (m) taken at center of plot.
DISTANCE TO EDGE	Distance to nearest microhabitat edge (m). Includes roads, openings, and streams, or any other significant edge in forest microhabitat.
CANOPY HEIGHT	Average canopy height (m).
SNAG	Number of snags/dead trees.
Ground cover:	
BARE GROUND	Percent of ground area covered by no vegetation.
GREEN	Percent of ground area covered by vegetation.
WATER	Percent of ground area covered by water.
LITTER	Percent of ground area covered by leaf litter.
MOSS	Percent of ground area covered by moss.
WOODY DEBRIS	Percent of ground area covered by woody debris.
Tree class categories:	
SAPLING	Number of trees <2.5 cm DBH.
POLE	Number of trees ≥2.5–8 cm DBH.
MID-SIZED TREE	Number of trees >8–38 cm DBH.
LARGE TREE	Number of trees >38 DBH.
Canopy cover:	
CANOPY 0–3 m	Mean canopy cover for <0.5–3 m.
CANOPY 3–6 m	Mean canopy cover for >3–6 m.
CANOPY 6–12 m	Mean canopy cover for >6–12 m.
CANOPY 12–24 m	Mean canopy cover for >12–18 m.
CANOPY ≥24 m	Mean canopy cover for >24 m.
VERTICAL STRUCTURE	Sum of all canopy "hits" with ocular sighting tube (min = 0, max = 120).

Mitchell et al. (2001), we did not eliminate any variables *a priori* from the analyses because little is known about Red-shouldered Hawk habitat use in a reclaimed mine landscape. The Hosmer and Lemeshow (H/L) Goodness-of-fit test was used to determine the fit of the logistic regression model. The entry and stay levels (α levels) for the logistic regression models were set at 0.3 and 0.1, respectively. We initially developed logistic regression models using all 48 points in all four treatments to determine if broad-scale features enabled Red-shouldered Hawks to persist in a reclaimed mine landscape. We then developed models for just the two forest treatments to more specifically examine features of fragmented and intact forest.

All statistical analyses were completed using the SAS® GLM, LOGISTIC, and TTEST procedures (SAS® Institute 1991). We set the significance level for all statistical tests at α = 0.1.

RESULTS

From February 2000–January 2001, we recorded 30 detections of Red-shouldered Hawks on broadcast surveys, with 19 of the 48 points having at least one detection. Of the four detections in shrub/pole, three were aural and one was visual. In fragmented forest, eight detections were aural, two were visual, and four were both. In intact forest, five detections were aural, two were visual, and four were both.

Mean abundance of Red-shouldered Hawks was significantly different among treatments (F = 2.57, df = 3, P = 0.053). The multiple comparison test indicated that mean abundance was significantly higher in the intact forest ($\bar{x}$ = 0.07 detections/point, SE = 0.03) than the grassland ($\bar{x}$ = 0.01, SE = 0.01) treatment but did not differ from the fragmented forest ($\bar{x}$ = 0.03, SE = 0.01) or shrub/pole ($\bar{x}$ = 0.03, SE = 0.01) treatments.

As expected, most microhabitat characteristics in both fragmented and intact forest differed from shrub/pole and grasslands (Table 3). Comparing fragmented and intact forest, the primary differences in microhabitat characteristics were greater

Table 3. Means and standard errors (SE) of microhabitat characteristics in grassland ($N = 44$), shrub/pole ($N = 33$), fragmented forest ($N = 36$), and intact forest ($N = 49$). Within a row, means with different letters differ at $P < 0.05$ (Waller-Duncan k-ratio test).

VARIABLE	GRASSLAND		SHRUB/POLE		FRAGMENT		INTACT		F	P
	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE		
ASPECT	1.05	0.10	0.77	0.11	1.05	0.12	1.03	0.08	1.86	0.1393
SLOPE (%)	16.96 B	2.10	10.16 C	1.93	33.78 A	2.28	33.75 A	2.07	42.95	<0.0001
ELEVATION (m)	400.27 A	7.47	378.85 B	11.53	332.08 C	7.11	399.47 A	11.24	24.94	<0.0001
DISTANCE TO EDGE (m)	113.02 A	16.75	68.14 B	8.23	38.71 B	3.88	64.61 B	11.57	4.69	0.0037
CANOPY HEIGHT (m)	—	—	4.68 B	0.46	21.77 A	0.73	22.98 A	0.67	222.63	<0.0001
SNAG (no./ha)	0.00 C	0.00	14.03 B	4.88	41.87 A	3.99	46.57 A	6.26	111.33	<0.0001
Ground Cover (%)										
BARE	7.73 B	1.18	2.22 B	0.92	7.71 A	0.95	7.45 A	0.59	13.19	<0.0001
GREEN	82.78 B	2.00	85.86 A	3.47	30.35 C	1.74	36.61 C	1.99	130.34	<0.0001
WATER	0.14 B	0.10	0.15 B	0.12	1.15 A	0.32	0.48 B	0.17	4.19	0.0070
LITTER	8.14 C	1.54	6.06 C	1.78	54.24 A	1.88	48.32 B	1.75	230.03	<0.0001
MOSS	1.04 B	0.38	1.83 B	0.86	2.01 A	0.32	2.04 A	0.34	5.48	0.0013
WOOD	0.06 B	0.04	0.30 B	0.12	4.20 A	0.42	4.95 A	0.41	140.93	<0.0001
Tree class categories (no./ha)										
SAPLING	777.70 B	207.52	7475.38 A	1646.08	4935.76 A	450.55	6135.84 A	702.59	67.03	<0.0001
POLE	73.15 C	18.79	979.17 B	292.52	901.04 A	65.86	587.37 AB	55.71	79.55	<0.0001
MID-SIZED TREE	0.03 C	0.02	132.58 B	23.72	429.17 A	35.26	352.93 A	12.90	565.54	<0.0001
LARGE TREE	0.00 B	0.00	0.00 B	0.00	44.27 A	3.77	42.35 A	3.17	993.28	<0.0001
Canopy cover (%)										
CANOPY 0–3 m	—		29.70 C	2.94	54.90 A	2.33	47.63 B	2.33	25.16	<0.0001
CANOPY 3–6 m	—		22.88 C	2.86	66.63 A	2.42	54.67 B	2.06	75.63	<0.0001
CANOPY 6–12 m	—		14.37 B	2.59	63.06 A	2.38	65.46 A	1.24	148.67	<0.0001
CANOPY 12–24 m	—		2.84 C	0.86	56.01 B	2.68	63.34 A	2.07	280.81	<0.0001
CANOPY 18–24 m	—		0.11 C	0.08	41.39 B	2.97	51.28 A	3.06	180.95	<0.0001
CANOPY ≥24 m	—		0.00 B	0.00	16.15 A	2.48	18.06 A	2.14	36.62	<0.0001
VERTICAL STRUCTURE	—		13.98 B	1.47	59.63 A	1.29	60.09 A	1.39	339.75	<0.0001

Table 4. Results of Student's *t*-tests showing mean and standard error (SE) of the 19 landscape variables within 1000-m buffer zones for presence/absence of Red-shouldered Hawks at 48 broadcast survey points in southern West Virginia during February 2000–January 2001.

| | ALL TREATMENTS[a] | | | | FOREST TREATMENTS[b] | | | |
| | PRESENCE | | ABSENCE | | PRESENCE | | ABSENCE | |
VARIABLE	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE
DEVELOPMENT	0.82	0.40	1.94	0.67	0.38	0.26	2.55	1.27
EARLY-SUCC. GRASS[c]	93.50	19.41	102.36	15.83	108.23	27.25	52.18	17.01
LATE-SUCC. CONIFER	19.41	4.06	16.52	3.40	23.65	5.40	17.86	4.64
LATE-SUCC. DECIDUOUS[c]	152.70	17.92	160.53	17.38	161.68	27.55	227.90	20.87
MID-SUCC. CONIFER[c]	3.24	2.21	2.02	1.26	0.00	0.00	0.06	0.03
MID-SUCC. DECIDUOUS	31.44	10.24	16.64	5.38	7.42	4.30	4.74	2.67
ROAD	9.10	1.51	10.47	2.10	8.68	2.27	5.99	1.99
WATER	1.79	0.45	1.54	0.25	1.70	0.44	1.01	0.37
WETLAND[c]	0.58	0.15	0.54	0.12	0.82	0.23	0.28	0.12
FOREST[c]	172.11	19.58	177.05	17.75	185.34	29.42	245.76	19.71
No. FOREST PATCHES	5.84	0.89	5.69	0.84	5.73	1.17	5.77	1.55
FOREST PATCH SIZE	61.95	20.65	80.87	20.34	83.73	34.47	140.06	39.09
CORE AREA	91.50	20.10	103.93	18.59	111.27	32.71	170.53	29.43
CORE PATCH SIZE	61.59	20.04	75.58	19.23	88.53	32.46	136.82	35.33
EDGE DENSITY	220.51	13.77	213.00	15.08	212.13	20.61	187.86	30.65
DIVERSITY INDEX	2.99	0.11	2.82	0.13	2.93	0.16	2.51	0.24
EVENNESS INDEX	0.73	0.02	0.72	0.01	0.70	0.02	0.70	0.02
DISTANCE TO WATER	378.02	102.78	407.75	76.97	437.37	173.82	600.85	149.12
DISTANCE TO TREATMENT	434.79	183.13	581.51	161.14	612.05	298.01	1034.15	318.51

[a] Includes all four treatments: grassland, shrub/pole, fragmented forest, and intact forest, $N = 48$.
[b] Includes fragmented forest and intact forest treatments only, $N = 24$.
[c] Indicates significant difference between means for the forest treatment at $\alpha = 0.1$.

amounts of water, litter, and low canopy (CANOPY 0–3 m, CANOPY 3–6 m) cover in fragmented forest. Intact forest generally had greater amounts of the higher canopy covers (CANOPY 12–18 m, CANOPY 18–24 m), although supercanopy cover (CANOPY 24 m) was similar between intact and fragmented forest.

At the landscape level, no variables were retained as predictors of Red-shouldered Hawk presence when all treatments were included in the logistic regression analyses. For the fragmented and intact forest points, the amount of wetland (WETLAND) in the landscape was the only predictor of presence (H/L Goodness-of-fit = 0.498, χ^2 = 3.580, $P = 0.059$). Additionally, wetlands occurred at 14 of the 19 points where Red-shouldered Hawks occurred, and wetland habitat was more abundant ($t = -2.21$, df = 22, $P = 0.038$) at forested points with Red-shouldered Hawk presence (Table 4). Student's *t*-tests indicated that early-successional reclaimed grassland habitat (EARLY-SUCC. GRASS) was more abundant, while late-successional forest

(LATE-SUCC. DECIDUOUS), mid-successional coniferous forest (MID-SUCC. CONIFER), and total mature forest (FOREST) were less abundant at forested points where Red-shouldered Hawks were present (Table 4).

DISCUSSION

Red-shouldered Hawks had significantly higher abundance in the intact forest treatment than the grassland treatment, but not compared to the fragmented forest or shrub/pole treatments. Observations of birds outside the treatment at the survey point were dropped from analyses, therefore, 18 of 23 detections (nine intact forest, four fragmented forest, four shrub/pole, one grassland) were used in statistical comparisons among treatments. When all 23 detections of Red-shouldered Hawks were classified into the habitat treatment where the bird occurred: 10 were in intact forest, eight in fragmented forest, four in shrub/pole, and one in grasslands. Many studies have shown these birds to nest primarily in contiguous, mature forest habitat

(Bednarz and Dinsmore 1981, Morris and Lemon 1983, Belleman 1998). During the study, only one Red-shouldered Hawk responded to broadcast surveys in fragmented forest during the breeding season (Balcerzak 2001). Overall, more Red-shouldered Hawks responded in intact forest during the breeding season (four detections), including one instance where two birds were observed together during a survey and may have been a nesting pair. Additionally, two–three Red-shouldered Hawks (possibly juveniles) were observed at an intact forest site in August, so breeding may have occurred in the area. Thus, it is possible that Red-shouldered Hawks may be using fragmented patches of forest for hunting or roosting, but using intact forest for nesting. Although analyses of microhabitat characteristics suggested few major differences between fragmented and intact forests, the amount of water as ground cover was greater in fragmented forests which may provide better foraging opportunities. Red-shouldered Hawks were detected in the shrub/pole and grassland treatment only during migration and winter periods (Balcerzak 2001). Some studies have reported greater use of more open areas and woodland edges by Red-shouldered Hawks during the winter months as compared to summer months (Bohall and Collopy 1984, Crocoll 1994).

The only significant predictor of Red-shouldered Hawk presence at the landscape level was the amount of WETLAND within the 1000-m buffer zone for points within the two forest treatments. WETLAND was not significant for the overall logistic regression models that included all 48 points and all treatments. Many of the ponds and wetlands in the study area occurred within the early-successional grassland found on the reclaimed mine sites. Throughout the year of surveys, only one juvenile Red-shouldered Hawk was detected flying over the open grassland of the mine, so any significance WETLAND may have had on Red-shouldered Hawk presence for the overall landscape regression models was mitigated by the low occurrence of Red-shouldered Hawks in the grasslands. The significance of the variable WETLAND for points within fragmented and intact forest, where a majority of Red-shouldered Hawk observations occurred, suggests that Red-shouldered Hawks are frequenting landscapes that contain a higher amount of wetlands, but that also are associated with mature forest. Amount of open water (WATER) and DISTANCE TO WATER/wetland

were not significant in any of the landscape regression models, suggesting that these two variables were not as important as the amount of palustrine emergent wetland habitat present in the landscape.

Wetlands have been associated with macrohabitat of Red-shouldered Hawks in a number of studies. Both Bednarz and Dinsmore (1981) and Bosakowski et al. (1992) found wetlands to be significant in the landscape surrounding Red-shouldered Hawk nests, while Howell and Chapman (1997) determined that a majority of Red-shouldered Hawk home ranges were within bottomland forest containing perennial streams, seasonal pools, and beaver ponds. Dykstra et al. (2001) found Red-shouldered Hawk response to broadcast surveys correlated with the number of small ponds within stream corridors. Red-shouldered Hawk association with wetlands may be related to diversity and abundance of amphibian prey. A majority of prey items delivered to Red-shouldered Hawk nests were prey associated with aquatic or moist habitats (Bednarz and Dinsmore 1981, Howell and Chapman 1997). Snakes, toads, lizards, and frogs are common prey for Red-shouldered Hawks in the eastern U.S. (Peterson and Crocoll 1992, Crocoll 1994). Many of the ponds and wetlands associated with the reclaimed grassland and fragmented forest in our study did contain populations of frogs, in particular bullfrogs (*Rana catesbeiana*).

Although most variables associated with the reclaimed mine present on the study sites (EARLY-SUCC. GRASS, MID-SUCC. DECIDUOUS DISTANCE TO TREATMENT) were not significant at a landscape scale in regression analyses, there was significantly more EARLY-SUCC. GRASS, and significantly less MID-SUCC. CONIFER, LATE-SUCC. DECIDUOUS, and FOREST at forest sites in the 1000-m buffer zone where Red-shouldered Hawks were present. This suggests that Red-shouldered Hawks can tolerate a measure of fragmentation (forest edge) within the landscape, which some studies have indicated may be important for foraging (Bednarz and Dinsmore 1982, Moorman and Chapman 1996). Although forested points where Red-shouldered Hawks were present contained more grassland and less forest overall, generally, multiple detections of Red-shouldered Hawks occurred at more intact forest points and few Red-shouldered Hawks were ever observed within reclaimed mine habitat, and then only dur-

ing the non-breeding season (Balcerzak 2001). The reclaimed portions of the three mines in our study were 1800–2500 ha in size, so such a large expanse of open land with little to no cover may have deterred Red-shouldered Hawks from using this habitat, regardless of the high amount of wetlands present. Generally, the grasslands had very few perches, especially adjacent to wetlands, which could explain low use of this area by hunting Red-shouldered Hawks. Bloom et al. (1993) found that Red-shouldered Hawks in California only used non-wooded areas when perches were present. Although wetlands were a significant factor determining Red-shouldered Hawk presence, this was only in combination with some mature forest present, indicating that the large size of the grasslands and lack of perches are likely the main reasons Red-shouldered Hawks were rarely observed using this habitat and associated wetlands.

In summary, our study, similar to others, found that the amount of wetland within a landscape containing mature forest is an important habitat characteristic determining presence of Red-shouldered Hawks. Many of the wetlands found along drainages of forested valleys within the landscape originated with fill ponds created to control soil erosion from reclaimed mine sites. Thus, it may be that Red-shouldered Hawks have taken advantage of the increased amount of wetlands created by past mining activities, but also need an undetermined amount of mature forest present. Interestingly, amount of grasslands and various measures of forest fragmentation were not important in predicting presence, even though Red-shouldered Hawks were rarely observed in grassland and shrub/pole habitat (Balcerzak 2001). Differences in seasonal use and limited sample size may have influenced this lack of pattern. The large size of the grasslands and lack of available perches for hunting likely contributed to low Red-shouldered Hawk use of reclaimed areas. More wetlands in the landscape may provide for a large population of amphibians and reptiles, important in the diet of Red-shouldered Hawks. Use of reclaimed lands by Red-shouldered Hawks might be enhanced and accelerated by planting hardwood trees near ponds and wetlands.

LITERATURE CITED

BALCERZAK, M.J. 2001. Raptor abundance and diversity and Red-shouldered Hawk (Buteo lineatus) habitat characteristics on reclaimed mountaintop mines in southern West Virginia. M.S. thesis, West Virginia University, Morgantown, WV U.S.A.

BEDNARZ, J.C. AND J.J. DINSMORE. 1981. Status, habitat use, and management of Red-shouldered Hawks in Iowa. J. Wildl. Manage. 45:236–241.

——— AND J.J. DINSMORE. 1982. Nest-sites and habitat of Red-shouldered and Red-tailed Hawks in Iowa. Wilson Bull. 94:31–45.

BELLEMAN, B.A. 1998. Red-shouldered Hawk breeding ecology and habitat use in central Minnesota. M.S. thesis, University of Minnesota, St. Paul, MN U.S.A.

BENT, A.C. 1937. Life histories of North American birds of prey. Part I. U.S. Natl. Mus. Bull. 167.

BLOOM, P.H., M.D. MCCRARY, AND M.J. GIBSON. 1993. Red-shouldered Hawks home-range and habitat use in southern California. J. Wildl. Manage. 57:258–265.

BOHALL, P.G. AND M.W. COLLOPY. 1984. Seasonal abundance, habitat use, and perch sites of four raptor species in north-central Florida. J. Field Ornithol. 55:181–189.

BOSAKOWSKI, T., D.G. SMITH, AND R. SPEISER. 1992. Status, nesting density, and macrohabitat selection of Red-shouldered Hawks in northern New Jersey. Wilson Bull. 104:434–446.

BUCKELEW, A.R. AND G.A. HALL. 1994. Red-shouldered Hawk Buteo lineatus. WV breeding bird atlas, University of Pittsburgh Press, Pittsburgh, PA U.S.A.

BUNN, A.G., W. KLEIN, AND K.L. BILDSTEIN. 1995. Time-of-day effects on the numbers and behavior of non-breeding raptors seen on roadside surveys in eastern Pennsylvania. J. Field Ornithol. 66:544–552.

CROCOLL, S.T. 1994. Red-shouldered Hawk (Buteo lineatus). In A. Poole and F. Gill [EDS.], The birds of North America, No. 107, The Academy of Natural Sciences Philadelphia, PA; The American Ornithologists' Union, Washington D.C. U.S.A.

——— AND J.W. PARKER. 1989. The breeding biology of Broad-winged and Red-shouldered Hawks in western New York. J. Raptor Res. 23:125–139.

DYKSTRA, C.R., F.B. DANIEL, J.L. HAYS, AND M.M. SIMON.

2001. Correlation of Red-shouldered Hawk abundance and macrohabitat characteristics in southern Ohio. *Condor* 103:652–656.

FORREN, J.D. 1981. Artificial perch use by raptors on reclaimed surface mines in West Virginia. M.S. thesis, West Virginia University, Morgantown, WV U.S.A.

FULLER, M.R. AND J.A. MOSHER. 1987. Raptor survey techniques. Pages 45–46 *in* B.A. Giron Pendleton, B.A. Millsap, K.W. Cline, and D.M. Bird [EDS.], Raptor management techniques manual. Natl. Wildl. Fed., Washington, DC U.S.A.

HALL, G.A. 1983. West Virginia birds: distribution and ecology. Spec. Publ. Carnegie Mus. Nat. Hist. No. 7, Pittsburgh, PA U.S.A.

HOWELL, D.L. AND B.R. CHAPMAN. 1997. Home range and habitat use of Red-shouldered Hawks in Georgia. *Wilson Bull.* 109:131–144.

JAMES, F.C. AND H.H. SHUGART. 1970. A quantitative method of habitat description. *Audubon Field Notes* 24:727–736.

KENNEDY, P.L. AND D.W. STAHLECKER. 1993. Responsiveness of nesting Northern Goshawks to taped broadcasts of three conspecific calls. *J. Wildl. Manage.* 57: 249–257.

McLEOD AND D.E. ANDERSEN. 1998. Red-shouldered Hawk broadcast surveys: factors affecting detection of responses and population trends. *J. Wildl. Manage.* 62: 1385–1397.

MINDELL, D.P. 1978. Habitat use by Red-tailed Hawks in surface mined areas. M.S. thesis, West Virginia University, Morgantown, WV U.S.A.

MITCHELL, M.S., R.A. LANCIA, AND J.A. GERWIN. 2001. Using landscape-level data to predict the distribution of birds on a managed forest: effects of scale. *Ecol. Appl.* 11:1692–1708.

MOORMAN, C.E. AND B.R. CHAPMAN. 1996. Nest-site selection of Red-shouldered and Red-tailed Hawks in a managed forest. *Wilson Bull.* 108:357–368.

MORRIS, M.M.J. AND R.E. LEMON. 1983. Characteristics of vegetation and topography near Red-shouldered

Hawk nests in southwestern Quebec. *J. Wildl. Manage* 47:138–145.

MOSHER, J.A. AND M.R. FULLER. 1996. Surveying woodland hawks with broadcasts of Great-horned Owl vocalizations. *Wildl. Soc. Bull.* 24:531–536.

———, M.R. FULLER, AND M. KOPENY. 1990. Surveying woodland raptors by broadcast of conspecific vocalizations. *J. Field Ornithol.* 61:453–461.

PETERSON FIELD GUIDE SERIES. 1990. Peterson field guide to bird songs of eastern and central North America. Cornell Laboratory of Ornithology/Interactive Audio, Houghton Mifflin Co., Boston, MA U.S.A.

PETERSON, J.M.C. AND S.T. CROCOLL. 1992. Red-shouldered Hawk, *Buteo lineatus.* Pages 333–351 *in* K.J. Schneider and D.M. Pence [EDS.], Migratory nongame birds of management concern in the Northeast. U.S. Dept. Inter., Fish and Wildl. Serv., Newton Corner, MA U.S.A.

PORTNOY, J.W. AND W.E. DODGE. 1979. Red-shouldered Hawk nesting ecology and behavior. *Wilson Bull.* 91. 104–117.

PRESTON, C.R. AND R.D. BEANE. 1993. Red-tailed Hawk (*Buteo jamaicensis*). *In* A. Poole and F. Gill [EDS.], The birds of North America, No. 52, The Academy of Natural Sciences, Philadelphia, PA; The American Ornithologists' Union, Washington, DC U.S.A.

ROSENFIELD, R.N., J. BIELEFELDT, AND R.K. ANDERSON. 1988. Effectiveness of broadcast calls for detecting breeding Cooper's Hawks. *Wildl. Soc. Bull.* 16:210–212.

SAS INSTITUTE, INC. 1991. SAS/STAT Guide for personal computers, 6th Ed. SAS Institute, Inc. Cary, NC U.S.A.

SAUER, J.R., J.E. HINES, AND J. FALLON. 2001. The North American breeding bird survey, results and analysis 1966–2000. Version 2001.2, USGS Patuxent Wildlife Research Center, Laurel, MD U.S.A.

STRAUSBAUGH, P.D. AND E.L. CORE. 1977. Flora of West Virginia. Seneca Books Inc., Morgantown, WV U.S.A.

TITUS, K. AND J.A. MOSHER. 1981. Nest-site habitat selected by woodland hawks in the central Appalachians. *Auk* 98:270–281.

EFFICACY OF MALE GOSHAWK FOOD-DELIVERY CALLS IN BROADCAST SURVEYS ON VANCOUVER ISLAND

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Abstract.—We conducted broadcast experiments at occupied Northern Goshawk (*Accipiter gentilis laingi*) nest sites on Vancouver Island, British Columbia, during the 1998 ($N = 8$) and 1999 ($N = 11$) breeding seasons to examine the potential of the untested male food-delivery call to improve detection rates. We compared the male food-delivery call to standard vocalizations used to locate Northern Goshawk nests during each breeding phase. An adult alarm and male food-delivery call were broadcast during the courtship (1999 only), nestling, and fledgling-dependency breeding phases, whereas a juvenile-begging call was broadcast only during the latter phase, when young were sufficiently developed to respond to calls. Northern Goshawks were detected at 52% ($N = 88$) of all broadcast trials. The male food-delivery call did not improve detection rates throughout the breeding season. Detection rates were lowest (40%) during courtship and highest (75%) during the fledgling-dependency phase. The distance we detected Northern Goshawks from nests with male food-delivery and alarm calls increased between courtship and nestling phases to the fledgling-dependency phase when the majority of detections shifted from adults to fledglings. Breeding phase did not influence the probability of detecting goshawks with male food-delivery and alarm calls. Broadcasting the juvenile-begging call within the fledgling-dependency phase increased the probability of detecting Northern Goshawks relative to the other two call types. The alarm and juvenile-begging calls remain the most effective for detecting Northern Goshawks on Vancouver Island during the nestling and fledgling-dependency periods, respectively. Dense coastal vegetation and rugged terrain may have interfered with our ability to project broadcast calls and to detect Northern Goshawks. The efficacy of broadcast surveys in Pacific Northwest forests during the nestling phase may be improved by spacing broadcast stations and transects at 200-m intervals, rather than the current standard of 300-m intervals, when detections occur close to nests. Broadcast stations and transects could be spaced 400-m apart during the fledgling-dependency phase when fledglings are detected farther from nest sites.

Key Words: *Northern Goshawk; Accipiter gentilis laingi; alarm call; broadcast surveys; juvenile-begging call; male food-delivery call; mixed models.*

EFICACIA DE LAS VOCALIZACIONES DE ENTREGA DE ALIMENTO DEL MACHO DE AZOR SEPTENTRIONAL EN INVESTIGACIONES HECHAS EN LA ISLA DE VANCOUVER

Resumen.—Llevamos a cabo experimentos con la emisión de vocalizaciones en los sitios de anidación ocupados por el azor septentrional (*Accipiter gentilis laingi*) en la Isla de Vancouver, British Columbia, durante las temporadas de crianza de 1998 ($N = 8$) y 1999 ($N = 11$) con el propósito de examinar el potencial de las vocalizaciones del macho a la entrega de alimento y con el fin de mejorar las tasas de detección de las mismas. Comparamos la vocalizacion de entrega de alimento del macho para su estandarización y para localizar nidos del azor septentrional durante cada fase de cría. Una vocalizacion de alarma del adulto y otra de entrega del alimento del macho se transmitieron durante el cortejo (sólo

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en 1999), la anidación, y las fases de apareamiento y dependencia de volantón, mientras que una vocalización de un juvenil pidiendo alimento se transmitió sólo durante la última fase, cuando los juveniles estuvieron lo suficientemente desarrollados para responder a las vocalizaciones. Los azores septentrionales se detectaron en 52% (N = 88) de todos los ensayos de emisión. La vocalizacion de entrega del alimento del macho, no mejoró las tasas de detección a través de la temporada de cría. Las tasas de detección fueron bajas (40%) durante el cortejo y altas (75%) durante la fase de dependencia del volantón. La distancia detectada desde los nidos con las vocalizaciones de entrega de alimento y de alarma, aumentaron entre el cortejo y la fase de anidación hasta la fase de dependencia del volantón, cuando la mayoría de las detecciones cambiaron de adultos a volantones. La fase de cría no influyó en la probabilidad de discernir las llamadas de entrega de alimento y de alarma. La emisión de la vocalizacion de juveniles pidiendo alimento dentro de la fase de dependencia de volantón aumentó la probabilidad de detectar a los parientes del azor septentrional de otros dos tipos de vocalizaciones. Las vocalizaciones de alarma y las de juveniles pidiendo alimento son las más efectivas para detectar azores septentrionales en la Isla de Vancouver durante los períodos de cría y de dependencia del volantón, respectivamente. La densa vegetación costera y el terreno escabroso pudieron haber interferido en nuestra habilidad de proyectar la emisión de las vocalizaciones y para detectar los azores. La eficacia en las emisiones en los bosques del noroeste del Pacífico durante la fase de cría pueden mejorarse espaciando las estaciones de transmisión y los transectos en intervalos de 200 m, en lugar de los intervalos estándar actuales de 300 m, cuando las detecciones se dan cerca de los nidos. Las estaciones de emisión y los transectos se podrían espaciar 400 m, durante la fase de dependencia de volantón cuando estos se detectan más lejos de los sitios de anidación.

[Traducción de César Márquez]

Techniques used to sample avian populations have come under recent scrutiny (Nichols et al. 2000, Rosenstock et al. 2002, Thompson 2002). In particular, scientists are concerned with sampling methods that generate abundance estimates that assume equal (and often 100%) detection rates across all species, age groups, habitat types, and time periods (Anderson 2001). Without incorporating detection probability functions into abundance estimates to adjust for these factors, the results produced are suspect, at best. Unbiased and accurate abundance estimates for avian populations are essential to monitor changes in population abundance, elucidate avian-habitat relationships, and detect population responses to environmental change (Rosenstock et al. 2002, Thompson 2002).

Abundance estimates for songbirds derived from point-count methodology have been the target of most sampling criticism. However, abundance estimates derived from broadcast surveys (also referred to as acoustic lure, call playback, or call response surveys) may be equally problematic because they are based on similar assumptions. Broadcast surveys are used to detect several elusive bird taxa including waterbirds (Legare et al. 1999, Erwin et al. 2002), frogmouths (Smith and Jones 1997), owls (Bosakowski and Smith 1998, Reid et al. 1999, Hardy and Morrison 2000), and hawks (Mosher and Fuller 1996, Bosakowski and Smith 1998, McLeod and Andersen 1998).

Broadcast surveys of conspecific calls are the most widely used technique to detect breeding Northern Goshawks (*Accipiter gentilis*; hereafter referred to as goshawk) throughout North America (New Mexico/Arizona: Kennedy and Stahlecker 1993, Arizona: Joy et al. 1994, Washington: Watson et al. 1999, British Columbia: McClaren 2001, Minnesota: Roberson 2001). Through broadcast survey experiments at known, occupied nests in Arizona and New Mexico, Kennedy and Stahlecker (1993) demonstrated broadcast surveys were 89% effective at detecting breeding goshawks and their young throughout the breeding season. They showed the alarm call was most effective during the nestling phase and the juvenile-begging call was most effective during the fledgling-dependency phase. Using similar experimental techniques in Washington, Watson et al. (1999) elicited 56% detection rates from breeding adults and their young. This suggests the effectiveness of broadcast surveys to detect breeding goshawks varies and may be influenced by habitat type, with detection rates being lower in the dense, coastal forests of the Pacific Northwest.

Variable, and perhaps, low, goshawk detection rates from broadcast surveys limit our ability to discern population trends and the influence of forest harvesting on breeding-habitat suitability. As a result, goshawk rates of population change and habitat associations remain unclear and are cont-rover-

sial (Crocker-Bedford 1998, Kennedy 1998, Smallwood 1998). In an effort to increase goshawk detection rates through broadcast surveys, we provide the first rigorous test of the male goshawk food-delivery call. This vocalization has been phonetically described as *kek. . .kek. . .kek* (Penteriani 2001), *guck* (Schnell 1958), or *chuuck* (Squires and Reynolds 1997) and will be defined in this paper as the male food-delivery call. Male goshawks use this vocalization frequently throughout the year to facilitate pair contact and prey deliveries (Penteriani 2001). For this reason, and from our field experience where adult females and fledglings seemed very responsive to males giving food-delivery calls (P. Kennedy, unpubl. data), we postulated this call would enhance our ability to detect breeding goshawks using broadcast surveys.

Our objectives were to modify Kennedy and Stahlecker's (1993) broadcast experiment to: (1) test the effectiveness of broadcasting a male food-delivery call, against an adult alarm and juvenile-begging call, for detecting goshawks at occupied nest sites during the breeding season; and (2) provide the first estimate of detection rates of the goshawk subspecies *A. g. laingi* in the dense coastal forests of Vancouver Island, British Columbia, Canada. This subspecies was federally listed in 2000 as Threatened in Canada (Cooper and Chytyk 2000) and Red-listed provincially in 1993 (Ministry of Environment, Lands and Parks 2000).

METHODS

Study Area. Forty goshawk nest areas were located on Vancouver Island, British Columbia between 1994–99 through goshawk inventory efforts and reports by forest company personnel and the public. We conducted broadcast experiment trials at 19 occupied nests within nest areas that were distributed widely throughout Vancouver Island. Nest sites were situated in the coastal western hemlock (CWH; *Tsuga heterophylla*) biogeoclimatic zone, the most productive temperate rainforest region in Canada (Pojar et al. 1991). The dominant tree species were western hemlock and Douglas-fir (*Pseudotsuga menziesii*), although western red cedar (*Thuja plicata*), amabilis fir (*Abies amabilis*), and red alder (*Alnus rubra*) were also abundant. Vancouver Island has rugged mountains dissected by many creek drainages. Elevations of nest sites ranged from 150–700 m. Mean daily temperatures range from 4.1°C in winter (October–April) to 14.3°C in summer (May–September). Mean monthly precipitation ranges from 40 mm in July to 234 mm in December, with a mean annual total of 1409 mm. Most precipitation falls as rain (Environment Canada 1998).

Broadcast Trials. We conducted broadcast trials at 8 and 11 goshawk nests, respectively, June to mid-August 1998, and April and mid-August 1999. These sample sizes

reflect all known occupied (determined during courtship) and active (determined during the nestling and fledgling-dependency phases) goshawk nests on Vancouver Island during these 2 yr. We considered nest areas occupied if females, radio-tagged by other investigations in 1997 and 1998, were present near nest sites or if untagged females were observed or heard vocalizing near nest sites. We considered nests active if nestlings or fledglings were observed. Our definitions of active and occupied are based on McClaren et al. (2002). In both years, we conducted trials during the nestling (June) and fledgling-dependency (early July to early August) stages of goshawk breeding phenology. In 1999 only, we also conducted trials during the courtship period (March to mid-April). We did not conduct broadcast trials during incubation because previous studies demonstrated female raptors were less likely to respond to broadcasts during this period (Fuller and Mosher 1981, Rosenfield et al. 1988), and broadcasts may disturb incubating females and cause egg loss. Also, we only conducted broadcast trials during the initial 25 d of the fledgling-dependency period when fledglings remain within 200–300 m of nests (Kenward et al. 1993, Kennedy et al. 1994). We added active nest sites to the experiment, as they were located, and deleted nest sites when they failed ($N = 2$) because goshawks are less likely to remain near nests after nest failure (Kennedy and Stahlecker 1993). To prevent pseudoreplication and habituation to broadcast calls, broadcast trials in 1999 only occurred at nest sites that held different breeding females than in 1998. We were less concerned about habituation of breeding males to broadcast calls because we expected most detections from the alarm call would be from females (Kennedy and Stahlecker 1993) and because the male food-delivery and juvenile-begging calls target adult females and fledglings.

When we confirmed nests were occupied by females or were active, we established transects following the experimental design of Kennedy and Stahlecker (1993). We spaced eight broadcast stations at 100-m intervals along 700 m transects, using a hip chain to measure distances. Transects were offset perpendicular from nest trees by 100 m to simulate a more realistic survey situation where the probability of transects intersecting nest trees is low (Kennedy and Stahlecker 1993). Thus, the first (farthest from nest tree) and last (closest to nest tree) broadcast stations were 707 m and 100 m from the nest tree, respectively. We oriented transects perpendicular to slopes to minimize topographic interference with sound projection. Most broadcast stations were entirely within the forest to minimize variation in detection abilities and sound projection among habitat types.

We used a commercially available adult goshawk alarm call (Western Bird Songs, Peterson Field Guides, Houghton Mifflin Company, Boston, MA) because we wanted our results to be comparable to other broadcast survey experiments and we wanted to simulate methodology used to locate breeding goshawks throughout North America. Trade name products are mentioned throughout the document to provide complete descriptions of methods. The authors' institutions neither endorse these products nor intend to discriminate against products not mentioned. In the absence of commercially-available recordings, we used a juvenile-begging call recorded by

A.C. Stewart (Ministry of Sustainable Resource Management, Victoria, BC) from Vancouver Island, and a male food-delivery call recorded by M. Robinson from a captive male goshawk in Waterford, Wisconsin. Broadcast calls were professionally recorded onto compact discs (CDs), background noise was removed, and recording levels were standardized so that broadcasting could occur at 100–110 dB (digital sound level meter model 33-2055: InterTan Canada Ltd., Barrie, Ontario, C-weighting [C-weighting is used to measure low frequency sounds that are >85 dB] 1 m from the audio source (Fuller and Mosher 1987) without distortion. We assumed that differences among call types were greater than regional variation within call types.

We used a portable CD player attached via a coaxial cable to a TOA® transistor megaphone (model: SPA-603, TOA Corporation, Kobe, Japan) to broadcast calls. Calls were played from 1-m above ground for 6 calling bouts of 10–12 sec separated by 30 sec of silence. We randomly determined the initial direction of the megaphone, and then rotated 120° to the right or left so that a full 360° was covered twice. We modified Kennedy and Stahlecker's (1993) methods by offsetting a second set of calls 60° from the first to increase the area covered by broadcasts. We also altered their design by following each broadcasting period with 5 min of looking and listening, thus providing 9 min of observation at each broadcast station. This modification was recommended for Vancouver Island by the Resource Inventory Committee (1997) and is consistent with field observations of goshawk detections following shorter broadcast sessions (E. McClaren, unpubl. data). During broadcast trials, E. McClaren recorded all goshawk detections in both years to avoid observer bias. She purposefully and systematically looked and listened in all directions to eliminate detection bias associated with prior knowledge of nest locations. Broadcast trials began at station 1 and were terminated as soon as goshawks were detected. We avoided visiting nests after trials to prevent goshawks from associating us with broadcast calls.

We broadcast adult alarm and male food-delivery calls during the courtship, nestling, and fledgling-dependency periods, whereas we broadcast the juvenile-begging call only during the fledgling-dependency period, when young were sufficiently developed to respond to this call. There were no silent walk-in controls for this experiment because broadcasting conspecific calls has been demonstrated to increase goshawk detection rates (Kennedy and Stahlecker 1993, Watson et al. 1999). Instead, we compared the male food-delivery call to the standard vocalizations used to locate goshawk nests during each breeding phase (Arizona: Joy et al. 1994, Oregon: United States Forest Service 1994, British Columbia: Resource Inventory Committee 1997, Minnesota: Kennedy and Andersen 1999, Alaska: Titus et al. 1999) to see if it enhanced detectability. The alarm call was compared with the male food-delivery call during the courtship and nestling phases. In the fledgling-dependency phase we compared the male food-delivery call with the juvenile-begging call.

We randomized broadcast trials at nests within each breeding stage (courtship, nestling, and fledgling-dependency) and within groups of nests that were geographically close, enabling sampling >1 transect/day. Once broadcast trials were initiated with one call type at a nest site, they were continued every 2 d until all call types were broadcast for that breeding phase. This design prevented differential detection rates from advances in chick development, and minimized temporally correlated detections. Trials were conducted 0800–2000 H; we did not design this experiment to test the influence of time of day on goshawk detection rates. We terminated trials in heavy rain or winds exceeding 20 km/hr. Trials interrupted by weather ($N = 2$) were repeated within 1–2 d.

At each broadcast station we recorded date, weather parameters (wind, cloud cover, cloud ceiling, precipitation, temperature), start/end time, detection type (auditory only, visual only, auditory and visual), detection latency (time in sec from start of broadcast session to detection), as well as gender (male, female, unknown) and age (adult, juvenile, unknown) of detected goshawks. We considered goshawk detections between stations ($N = 8$) to be associated with the previous broadcast station. Latencies were calculated from the start of that station's broadcast session until the time of detection.

Statistical Analyses. We evaluated the success of broadcast surveys, relative to broadcast call type and breeding phase, in 3 ways: (1) detection rates; (2) the distance of detections from occupied nests, as this influences the likelihood of locating nest sites; and (3) the probability of detecting a goshawk, with each call type, during each breeding phase. Detection latencies were also analyzed in relation to breeding phase and broadcast call type to determine the optimal amount of time a surveyor should spend at each broadcast station.

Goshawk detection rates were calculated as the number of goshawk detections per number of broadcast trials. We used a chi-square analysis to test for differences in detection rates among broadcast calls and breeding phases. However, this analysis treats broadcast trials conducted at the same nest sites with the same call types in different breeding phases independently, as other studies have done (Kennedy and Stahlecker 1993, Watson et al. 1999). We reanalyzed the data using mixed models, which incorporates the influence of these repeated measures on experimental results. Failure to include repeated measures in models in the following analyses could cause P-values to be inaccurate.

We analyzed the influence of broadcast call type and breeding phase on detection distance (from occupied nests) and detection latency with mixed linear regression models (Littell et al. 1996). Because the experimental design was unbalanced (juvenile-begging calls were only broadcast during one breeding phase in both years, and the courtship phase was tested in only 1 yr), analyses were performed on three data subsets (Table 1). Preliminary analyses provided no evidence that the fixed effects of year, year × broadcast call, and year × breeding phase influenced detection distance (Table 1b [year: $F_{1,6} = 0.01$, $P = 0.94$; year × broadcast call: $F_{1,10} = 0.10$, $P = 0.76$; year × breeding phase: $F_{1,3} = 0.60$, $P = 0.49$]; Table 1c [year: $F_{1,11} = 1.03$, $P = 0.33$; year × broadcast call: $F_{2,15} = 0.31$, $P = 0.74$]). Therefore, we pooled the 1998 and 1999 data except when the courtship phase was included. Fixed effects in mixed linear regression models included breeding phase, broadcast call type, and their interaction. Random effects were nest site and its inter-

Table 1.   Three data matrices used in mixed linear and logistic regression models to accommodate an unbalanced experimental design.

CALL TYPE/YEAR	BREEDING PHASE		
a) Alarm and male food-delivery calls. 1999	courtship	nestling	fledgling-dependency
b) Alarm and male food-delivery calls. 1998, 1999		nestling	fledgling-dependency
c) Alarm, male food-delivery, and juvenile-begging calls. 1998, 1999			fledgling-dependency

actions with broadcast call type and breeding phase. The term nest site × breeding phase accommodated the influence of repeated transects at the same nest sites (using different call types) within the same breeding phase on experimental results. Likewise, the term nest site × call type incorporated the repeated measures associated with broadcasting alarm and male food-delivery calls during three breeding phases. We square-root transformed detection distances and latencies to decrease the heterogeneity of variances associated with large values. We assessed normality assumptions of mixed linear regression models with studentized residual versus predicted plots and concluded the models in the above analyses were appropriate for the data sets. We compared least square mean detection distances and latencies of broadcast calls within and between breeding phases using pairwise t-tests. We did not perform multiple comparison adjustments because comparisons were chosen a priori and sample sizes were small. Therefore, we controlled comparison-wise error rates in our analyses.

The influence of broadcast call type and breeding phase on the probability of detecting a goshawk (0 = no detection, 1 = detection) was analyzed using mixed logistic regression models (McCulloch and Searle 2001). We analyzed the three data subsets (Table 1) combining years for analyses that did not include the courtship phase because all year and year interactions were nonsignificant in the previous analyses. As with mixed linear regression models, the fixed effects included broadcast call type, breeding phase, and their interaction. Nest site, the random effect in these models, was used to incorporate variability in detection rates caused by differences in detection probabilities among individual goshawks. Designating nest site as a random effect accommodated problems associated with repeated measures on the same nest sites (sampling the same nest sites using alarm and

male food-delivery calls, during three breeding phases). We assumed random effects in mixed logistic models were normally distributed. All analyses were performed using SAS Version 7.0 (SAS Institute 1989).

RESULTS

Detection Rates. Goshawks were detected on 52% of broadcast trials ($N = 88$). In courtship, detection rates were 40% for both the male food-delivery and alarm calls (Table 2). In the nestling phase, detection rates were 60% with the alarm call and 40% with the male food-delivery call, but this difference was not statistically significant ($\chi^2 = 1.20$, $P = 0.27$; Table 2). Detection rates were highest (75%) in the fledgling-dependency phase when the juvenile-begging call was broadcast. However, detection rates were not significantly different among the three call types within this phase ($\chi^2 = 3.56$, $P = 0.17$; Table 2). Goshawks were detected at least once at all but one nest site, after broadcast trials were completed.

For all breeding phases and broadcast calls combined, 83% of goshawk detections were only auditory, 2% were only visual, and 15% were auditory and visual. During the courtship phase (pooled over broadcast call type), all detections were auditory. In the nestling phase, 53% of detections were only auditory and 40% were a combined auditory and visual detection. Detections during the fledgling-dependency phase were primarily auditory

Table 2.   Goshawk detection rates (detections/total trials) during broadcast experiments on Vancouver Island, British Columbia, 1998–99.

| BROADCAST CALL	BREEDING PHASE			
	COURTSHIP	NESTLING	FLEDGLING-DEPENDENCY	CALL TOTALS
Male food-delivery	2/5	6/15	8/16	16/36
Alarm	2/5	9/15	7/16	18/36
Juvenile-begging	NS[a]	NS	12/16	12/16
Phase totals	4/10	15/30	27/48	46/88

[a] Not sampled.
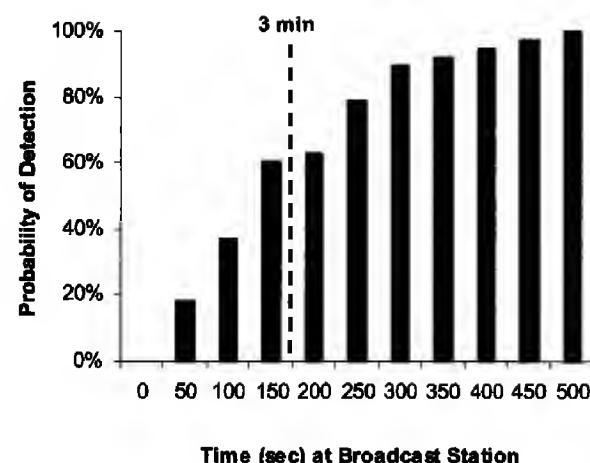
Figure 1. Cumulative probability of detecting goshawks as a function of time spent at broadcast stations during broadcast experiment trials on Vancouver Island, British Columbia, 1998–99. Our study is compared to other studies that spent 3 min at broadcast stations (Kennedy and Stahlecker 1993, Watson et al. 1999).

only (96%). Similarly, detections for each broadcast call, pooled over breeding phase, were mainly auditory only [male food-delivery call (81%), alarm call (72%), juvenile-begging call (100%)].

Only 39% of detections during broadcast trials were of adult goshawks. During courtship, only adults were available for detection. In the nestling phase, 80% of detections were of adults whereas in the fledgling-dependency phase, 93% of detections were of fledglings. Pooled over breeding phase, the male food-delivery call primarily generated fledgling detections (62%), whereas the alarm call primarily generated adult detections (67%). All detections from the juvenile-begging call were of fledglings.

Detection Latency. We recorded 63% of detections at broadcast stations within 3 min of initiating broadcast calls and 90% of detections within 5 min of initiating broadcast calls (Fig. 1). In other words, 63% of detections occurred after we broadcast three sets of calls and 90% of detections occurred after we broadcast six sets of calls plus a 1 min listening period. Mean detection latencies did not significantly differ between call types within the nestling and fledgling-dependency phases (all pairwise comparison P-values > 0.05).

Detection Distance from Occupied Nests. All detections during the courtship and nestling phases with the male food-delivery call were 141 m from nests (Figs. 2a, 2b). However, in the fledgling-dependency phase we detected goshawks with the male food-delivery call throughout transect distances and as far as 707 m from nests (Fig. 2c). From courtship through fledgling-dependency,
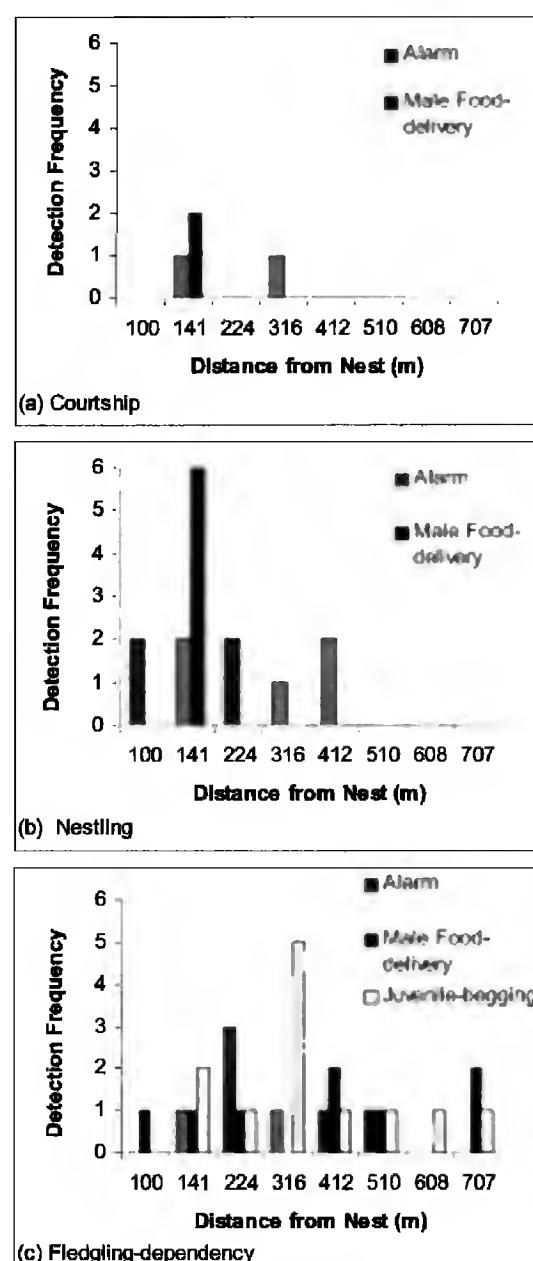

Figure 2. Frequency of goshawk detections as a function of distance from occupied nests, Vancouver Island, British Columbia, 1998–99. Graphs are presented for the (a) courtship, (b) nestling, and (c) fledgling-dependency phases.

goshawks were detected with alarm calls at progressively farther distances from nests. However, greater than 70% of alarm call detections were within 316 m of nests during all breeding phases. With the juvenile-begging call, goshawks were detected 141–707 m from nests but most frequently they were detected at 316 m from nests (Fig. 2c).

Breeding phase influenced the distance we detected goshawks from occupied nests (Fig. 3). The most dramatic pattern we observed was with the male food-delivery call. The mean distance we detected goshawks with the male food-delivery call increased from the courtship ($t = 3.07$, $P = 0.01$) and nestling ($t = 3.64$, $P = 0.003$) phases to the fledgling-dependency phase (Fig. 3). Mean detection distances were similar ($F_{2,17} = 0.79$, $P = 0.47$;
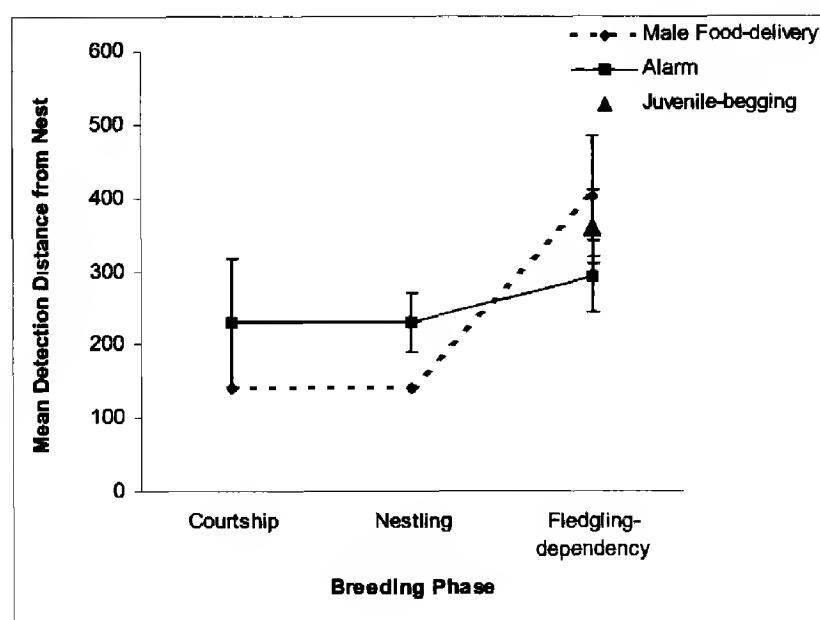
Figure 3. Mean ± SE goshawk detection distance (m) from occupied nests during broadcast experiment trials on Vancouver Island, British Columbia, 1998–99.

Fig. 3) for the three calls in the fledgling-dependency phase.

Detection Probability. The probability of detecting goshawks did not significantly depend on which call type was broadcast within the courtship and nestling phases ($t = -0.28$, $P = 0.78$, $N = 56$), nor did detection probabilities change for a given call type between breeding phases ($t = 0.73$, $P = 0.47$, $N = 56$). However, in the fledgling-dependency phase, broadcasting the juvenile-begging call increased the probability of detecting goshawks relative to alarm and male food-delivery calls ($t = 1.97$, $P = 0.07$, $N = 48$).

DISCUSSION

Efficacy of the Male Food-delivery Call. The probability of detecting goshawks or their young was not increased by broadcasting the male food-delivery call during the courtship, nestling, or fledgling-dependency breeding phases, relative to the standard alarm (courtship, nestling) and juvenile begging (fledgling-dependency) calls. Although not statistically significant, detection rates were higher when alarm and juvenile-begging calls were broadcast during the nestling and fledgling-dependency phases, respectively, relative to broadcasts of the male food-delivery call. Non-statistical differences in our detection rates may reflect small sample sizes as a result of relatively low breeding densities of goshawks on Vancouver Island. However, the 20% and 25% difference in detection rates we observed between the male food-delivery

call and alarm and juvenile-begging calls during the nestling and fledgling-dependency phases, respectively, may reflect biologically meaningful differences. Thus, we recommend the continued use of standard calls until a more effective call type is identified.

The male food-delivery call may not be as effective as alarm and juvenile-begging calls in broadcast surveys because it is naturally a call of low pitch and volume that is given by the male when he is delivering food to the nest (Schnell 1958, Squires and Reynolds 1997, Penteriani 2001). Consequently, broadcasting this call at 100–110 dB may be unrealistic and may alter the call's identity. The male's physical presence in the nest stand, as well as his food-delivery call, may stimulate the response. Because this call is used for pair contact, goshawks may utilize individual variation in this call to recognize their mates compared to the alarm and juvenile-begging calls which have more generalized usage. Therefore, when we broadcast a recording from Wisconsin on Vancouver Island, females may have been less responsive to our recording. However, Roberson (2001) later tested the same recording of the male food-delivery call in Minnesota and reported lower detection rates than our study. This suggests that our results are not an artifact of dialect.

Geographic Variation in Detection Rates. Overall, detection rates for alarm and juvenile-begging calls in this study were lower than those reported by Kennedy and Stahlecker (1993). Kimmel and Yahner (1990) and Watson et al. (1999) also reported lower detection rates than Kennedy and Stahlecker (1993). For example, Kennedy and Stahlecker (1993) reported detection rates of 93% with the alarm call during the nestling phase, compared to 60% (this study), 37% (Watson et al. 1999), and 48% (Kimmel and Yahner 1990). Kennedy and Stahlecker (1993) also reported higher detection rates during the fledgling-dependency phase with the juvenile-begging call (85%) than recorded in this experiment (75%) and by Watson et al. (1999; 74%). Regional variation in goshawk detection rates reinforces that local detection probability functions should be incorporated when broadcast data are used to monitor changes in population abundance, elucidate goshawk-habitat relationships, and detect population responses to environmental change.

Lower detection rates in the Pacific Northwest compared to the southwestern United States sug-

gest that transmission of broadcast calls in coastal forests may be hindered by vegetation and topography. These factors may also reduce an observer's ability to detect goshawks, visually and aurally, in coastal forests. Other studies have also expressed, but have not documented experimentally, concerns regarding lower goshawk detection rates with broadcast surveys in coastal forests (southeast Alaska: Iverson et al. 1996; western Oregon: DeStefano and McCloskey 1997; western Washington: Bosakowski and Vaughn 1996). A large body of literature from songbird broadcast experiments documents the scattering of sound by reflective surfaces such as foliage and tree trunks (Fotheringham and Ratcliffe 1995, Brown and Handford 2000). Tree density within goshawk nest areas on Vancouver Island (Ethier 1999) is higher than in New Mexico (Siders and Kennedy 1996) which may degrade broadcast calls. Many songbirds use sound degradation to gauge the distance of an intruder from their territory (Fotheringham and Ratcliffe 1995, Holland et al. 1998). Similarly, goshawks may gauge the distance of broadcast calls and if calls appear far away, they may be less responsive.

Survey Design and the Probability of Detecting a Goshawk. It is important to streamline broadcast surveys so that they occur when they are most effective. Depending on the objective of broadcast surveys, efficacy will be measured by number of detections, number of occupied nests located or both. Breeding phase, call type, distance between broadcast stations and transect lines, and the amount of time spent at each broadcast station will influence the success of broadcast surveys and the amount of time, effort and money expended.

Breeding phase and call type. Detection rates with alarm and male food-delivery calls were similar between the nestling and the fledgling-dependency breeding phases. Our results were similar to conclusions made by Kimmel and Yahner (1990) who broadcast goshawk alarm calls during the nestling and fledgling phases. Conversely, breeding phase influenced the probability of detecting goshawks throughout the breeding season in experiments conducted by Kennedy and Stahlecker (1993). However, they compared differences in combined detection rates from alarm and wail calls during the nestling phase to rates from alarm, wail, and juvenile-begging calls during the fledgling-dependency phase. Thus, it is difficult to ascertain whether Kennedy and Stahlecker (1993) obtained significant results because the effectiveness of individual

call types differed between breeding phases or because overall detection rates significantly increased between the nestling and fledgling phases. Total detection rates in our study were also greater in the fledgling-dependency phase compared to the nestling and courtship phases.

Breeding phase influenced the distance goshawks were detected from occupied nests with the mean distance of detection for alarm and male food-delivery calls increasing between the nestling and fledgling-dependency phases. These trends are consistent with other broadcast experiments on goshawks (Kimmel and Yahner 1990, Kennedy and Stahlecker 1993, Watson et al. 1999). Increased mean detection distances with alarm and male food-delivery calls between breeding phases reflects the shift from adults comprising most detections during the courtship and nestling phases, to primarily fledglings during the fledgling-dependency phase. In general, adults are secretive and reveal their presence when intruders or male goshawks are perceived as being close to nests, whereas fledglings often approach observers on transects because male food-delivery (this study), wail (Kennedy and Stahlecker 1993), and juvenile-begging calls (Kennedy and Stahlecker 1993, Watson et al. 1999, this study), probably suggest the likelihood of obtaining food.

Although detection rates were not significantly different among breeding phases in our study, detection rates were 75% in the fledgling-dependency phase, compared with 60% in the nestling phase. However, it is more difficult to locate occupied nests during the fledgling-dependency phase because detections occur farther from nests. To maximize the probability of locating occupied nests, broadcast surveys should be conducted a minimum of twice throughout the breeding season (once during each of the nestling and fledgling-dependency phases). Nest areas should be surveyed a minimum of two consecutive nesting seasons because goshawk nest areas are not always occupied annually (Kennedy and Stahlecker 1993).

Distance between broadcast stations and transect lines. The distances goshawks are detected from active nests influences the optimal spacing of broadcast stations and transect lines. Given that detection rates generally decrease when observers are farther from nests (Kennedy and Stahlecker 1993, Watson et al. 1999, this study), observers are less likely to detect goshawks as the spacing between broadcast stations and transects is increased. Kennedy and

Stahlecker (1993) recommended broadcast stations be located 300-m apart on parallel transects separated from each other by 260 m, and stations on adjacent transects should be offset by 130 m to maximize coverage, because they assumed that goshawk detections were maximum within 100–200 m of occupied nests. Results from this study and Watson et al. (1999) suggest that broadcast surveys in dense, coastal forests could be improved during the nestling phase if broadcast stations and transects are separated by 200 m, with parallel transects being offset from one another by 100 m. Because fledglings are detected at greater distances from nests during the fledgling-dependency phase, broadcast stations and transects conducted during this time could be separated by 400 m to maximize survey efficiency. Staggering adjacent transects by half the distance between broadcast stations maximizes the area covered by calls (Joy et al. 1994).

Time spent at broadcast stations. The time we spent at broadcast stations also appeared to influence our likelihood of detecting goshawks. In our experiment, 37% ($N = 14$) of detections occurred beyond the 3 min/station practiced by other researchers (Kennedy and Stahlecker 1993, Watson et al. 1999). Our results suggest the optimal amount of time/station is 5 min in dense coastal forests. Sampling for 5 min/broadcast station or six calls plus a 1 min listening period, increases the probability of detecting goshawks at nearby occupied nests, while enabling broadcast surveys to be conducted more efficiently than when observers spend 9 min/station. However, 9 min/station is recommended if surveyors wish to maximize detection probabilities without time constraints.

ACKNOWLEDGMENTS

LITERATURE CITED

ANDERSON, D.R. 2001. The need to get the basics right in wildlife field studies. *Wildl. Soc. Bull.* 29:1294–1297

BOSAKOWSKI, T. AND D.G. SMITH. 1998. Response of a forest raptor community to broadcasts of heterospecific and conspecific calls during the breeding season. *Can. Field-Nat.* 112:198–203.

——— AND M.E. VAUGHN. 1996. Developing a practical method for surveying Northern Goshawks in managed forests of the western Washington Cascades. *West. J. Appl. For.* 11:109–113.

BROWN, T.J. AND P. HANDFORD. 2000. Sound design for vocalizations: quality in the woods, consistency in the fields. *Condor* 102:81–92.

COOPER, J.M. AND P. CHYTYK. 2000. Draft status report on the Queen Charlotte Goshawk *Accipiter gentilis laingi* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON Canada.

CROCKER-BEDFORD, D.C. 1998. The value of demographic and habitat studies in determining the status of Northern Goshawks (*Accipiter gentilis atricapillus*) with special reference to Crocker-Bedford (1990) and Kennedy (1997). *J. Raptor Res.* 32:329–335.

DESTEFANO, S. AND J. MCCLOSKEY. 1997. Does vegetation structure limit the distribution of Northern Goshawks in the Oregon coast ranges? *J. Raptor Res.* 31:34–39.

ENVIRONMENT CANADA. 1998. Canadian climate normals 1961–1990: Campbell River airport, British Columbia Retrieved September 13, 2001 from the World Wide Web: http://www.cmc.ec.gc.ca/climate/normals/BCC002.HTM.

ERWIN, R.M., C.J. CONWAY, AND S.W. HADDEN. 2002. Species occurrence of marsh birds at Cape Cod National Seashore, Massachusetts. *Northeast. Nat.* 9:1–12.

ETHIER, T.J. 1999. Breeding ecology and habitat of Northern Goshawks (*Accipiter gentilis laingi*) on Vancouver Island: a hierarchical approach. M.S. thesis, University of Victoria, Victoria, BC Canada.

FOTHERINGHAM, J.R. AND L. RATCLIFFE. 1995. Song degradation and estimation of acoustic distance in Black-capped Chickadees (*Parus atricapillus*). *Can. J. Zool.* 73:858–868.

FULLER, M.A. AND J.A. MOSHER. 1981. Methods of detecting and counting raptors: a review. *Stud. Avian Biol.* 6. 235–246.

——— AND ———. 1987. Raptor survey techniques. Pages 37–65 *in* B.A. Giron Pendleton, B.A. Millsap, K.W. Cline, and D.M. Bird [EDS.], Raptor management techniques manual. Nat. Wildl. Fed. Sci. Tech. Ser No. 10, Washington, DC U.S.A.

HARDY, P.C. AND M.L. MORRISON. 2000. Factors affecting the detection of Elf Owls and Western Screech-Owls. *Wildl. Soc. Bull.* 28:333–343.

HOLLAND, J., T. DABELSTEEN, AND S.B. PEDERSEN. 1998. Degradation of wren *Troglodytes troglodytes* song: impli-

cations for information transfer and ranging. *J. Acoust. Soc. Am.* 103:2154–2166.

IVERSON, G.C., G.D. HAYWARD, K. TITUS, E. DEGAYNER, R.E. LOWELL, D.C. CROCKER-BEDFORD, P.F. SCHEMPF, AND J. LINDELL. 1996. Conservation assessment for the Northern Goshawk in southeast Alaska. Gen. Tech. Rep. PNW-GTR-387, USDA, USFS, Pacific Northwest Research Station, Portland, OR U.S.A.

JOY, S.M., R.T. REYNOLDS, AND D.G. LESLIE. 1994. Northern Goshawk broadcast surveys: hawk response variables and survey costs. *Stud. Avian Biol.* 16:24–30.

KENNEDY, P.L. 1998. Evaluating Northern Goshawk (*Accipiter gentilis atricapillus*) population trends: a reply to Smallwood and Crocker-Bedford. *J. Raptor Res.* 32: 336–341.

——— AND D.E. ANDERSEN. 1999. Research and monitoring plan for Northern Goshawks (*Accipiter gentilis atricapillus*) in the Western Great Lakes Region. Retrieved March 29, 2000 from the World Wide Web: http://www.fw.umn.edu/CO-OP/download/default.html.

——— AND D.W. STAHLECKER. 1993. Responsiveness of nesting Northern Goshawks to taped broadcasts of 3 conspecific calls. *J. Wildl. Manage.* 57:249–257.

———, J.M. WARD, G.A. RINKER, AND J.A. GESSAMAN. 1994. Post-fledgling areas in Northern Goshawk home ranges. *J. Avian Biol.* 16:75–82.

KENWARD, R.E., V. MARCSTROM, AND M. KARLBOM. 1993. Post-nesting behaviour in goshawks, *Accipiter gentilis*: I. The causes of dispersal. *Anim. Behav.* 46:365–370.

KIMMEL, J.T. AND R.H. YAHNER. 1990. Response of Northern Goshawks to taped conspecific and Great Horned Owl calls. *J. Raptor Res.* 24:107–112.

LEGARE, M.L., W.R. EDDLEMAN, P.A. BUCKLEY, AND K. COLLEEN. 1999. The effectiveness of tape playback in estimating Black Rail density. *J. Wildl. Manage.* 63:116–125.

LITTELL, R.C., G.A. MILLIKEN, W.W. STROUP, AND R.D. WOLFINGER. 1996. SAS system for mixed models. SAS Institute, Cary, NC U.S.A.

MCCLAREN, E.L. 2001. Factors influencing Northern Goshawk detectability and reproduction on Vancouver Island, British Columbia. M.S. thesis, Colorado State University, Fort Collins, CO U.S.A.

MCCLAREN, E.L., P.L. KENNEDY, AND S.R. DEWEY. 2002. Do some Northern Goshawk nest areas fledge more young than others? *Condor* 104:343–352.

MCCULLOCH, C.E. AND S.R. SEARLE. 2001. Generalized, linear, and mixed models. Wiley Series in Probability and Statistics. John Wiley and Sons, Inc., New York, NY U.S.A.

MCLEOD, M. AND D.E. ANDERSEN. 1998. Red-shouldered Hawk broadcast surveys: factors affecting detection of responses and population trends. *J. Wildl. Manage.* 62: 1385–1397.

MINISTRY OF ENVIRONMENT, LANDS AND PARKS. 2000. 2000

Red and Blue lists for amphibians, reptiles, birds and mammals. Victoria, BC Canada.

MOSHER, J.A. AND M.R. FULLER. 1996. Surveying woodland hawks with broadcasts of Great Horned Owl vocalizations. *Wildl. Soc. Bull.* 24:531–536.

NICHOLS, J.D., J.E. HINES, J.R. SAUER, F.W. FALLON, J.E FALLON, AND P.J. HEGLUND. 2000. A double-observer approach for estimating detection probability and abundance from point counts. *Auk* 117:393–408.

PENTERIANI, V. 2001. The annual and diel cycles of goshawk vocalizations at nest sites. *J. Raptor Res.* 35:24–30.

POJAR, J.E., K. KLINKA, AND D.A. DEMARCHI. 1991. Coastal western hemlock biogeoclimatic zone. Pages 95–112 in D.V. Meidinger and J.E. Pojar [EDS.], Ecosystems of British Columbia. Spec. Rep. Ser. No. 6. British Columbia Ministry of Forests Research Branch, Victoria, BC Canada.

REID, J.A., R.B. HORN, AND E.D. FORSMAN. 1999. Detection rates of Spotted Owls based on acoustic-lure and live-lure surveys. *Wildl. Soc. Bull.* 27:986–990.

RESOURCE INVENTORY COMMITTEE. 1997. Standard inventory methodologies for components of British Columbia's biodiversity: raptors. Version 1.1. Ministry of Environment, Lands and Parks, Wildlife Branch, Victoria, BC Canada.

ROBERSON, A.M. 2001. Evaluating and developing survey techniques using broadcast conspecific calls for Northern Goshawks in Minnesota. M.S. thesis, University of Minnesota, St. Paul, MN U.S.A.

ROSENFIELD, R.N., J. BIELEFELDT, AND R.K. ANDERSON 1988. Effectiveness of broadcast calls for detecting breeding Cooper's Hawks. *Wildl. Soc. Bull.* 16:210–212.

ROSENSTOCK, S.S., D.R. ANDERSON, K.M. GIESEN, T. LEUKERING, AND M.F. CARTER. 2002. Landbird counting techniques: current practices and an alternative. *Auk* 119:46–53.

SAS INSTITUTE. 1989. SAS/STAT user's guide. Version 6.12. Fourth Ed. SAS Institute, Cary, NC U.S.A.

SCHNELL, J.H. 1958. Nesting behavior and food habits of goshawks in the Sierra Nevada of California. *Condor* 60:377–403.

SIDERS, M.S. AND P.L. KENNEDY. 1996. Forest structural characteristics of *Accipiter* nesting habitat: is there an allometric relationship? *Condor* 98:123–132.

SMALLWOOD, K.S. 1998. On the evidence needed for listing Northern Goshawks (*Accipiter gentilis*) under the Endangered Species Act: a reply to Kennedy. *J. Raptor Res.* 32:323–329.

SMITH, G.C. AND D.N. JONES. 1997. Vocalisations of the marbled frogmouth I: descriptions and analysis of sex differences. *Emu* 97:290–295.

SQUIRES, J.R. AND R.T. REYNOLDS. 1997. Northern Goshawk (*Accipiter gentilis*). Pages 1–32 in A. Poole and F. Gill [EDS.], The Birds of North America, No. 298. The Academy of Natural Sciences, Philadelphia, PA U.S.A.,

and The American Ornithologists' Union, Washington, DC U.S.A.

THOMPSON, W.L. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. *Auk* 119:18–25.

TITUS, K., C. FLATTEN, AND R. LOWELL. 1999. Goshawk ecology and habitat relationships on the Tongass National Forest. 1998 annual report. Study SE-4-2. Alaska Department of Fish and Game, Division of Wildlife Conservation, Juneau, AK U.S.A.

UNITED STATES FOREST SERVICE. 1994. Goshawk monitoring, management, and research in the Pacific Northwest region: 1994 status report. USDA, USFS, Portland, OR U.S.A.

WATSON, J.W., D.W. HAYS, AND D.J. PIERCE. 1999. Efficacy of Northern Goshawk broadcast surveys in Washington State. *J. Wildl. Manage.* 63:98–106.

REPRODUCTIVE SUCCESS, ENVIRONMENTAL CONTAMINANTS, AND TROPHIC STATUS OF NESTING BALD EAGLES IN EASTERN NEWFOUNDLAND, CANADA

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ABSTRACT.—Eastern Newfoundland contains a large breeding population of Bald Eagles (*Haliaeetus leucocephalus*). Our objectives were to determine the reproductive success, contaminant levels, and trophic status of Bald Eagles in eastern Newfoundland, and to compare contaminant levels of eagles in industrialized and nonindustrialized coastal bays (Placentia and Bonavista bays, respectively). Bald Eagle breeding density in eastern Newfoundland was 0.09 occupied nests/km shoreline, and reproductive success suggested a healthy population (1.1 young/occupied nest). Geometric mean concentrations of PCBs and DDE in nestling plasma were significantly higher in Placentia Bay (PCBs = 30.0 ng/g [wet wt]; DDE = 9.0 ng/g) than in Bonavista Bay (PCBs = 10.0 ng/g; DDE = 2.0 ng/g). Within Placentia Bay, concentrations of PCBs and DDE in nestlings were negatively related to the nest distance from the former U.S. naval base at Argentia. Geometric mean concentration of mercury in whole blood of eagle nestlings was 87 ng/g (wet wt). Analysis of prey remains collected at nests and of stable-carbon (^{13}C/^{12}C) and nitrogen (^{15}N/^{14}N) isotope ratios in nestling blood indicated some differences between nests in food sources, but not in relative trophic level. Prey remains collected at 30 Bald Eagle nests were composed of 64% birds, 29% fish, and 7% mammals. Contaminant burdens in Bald Eagles in eastern Newfoundland were lower than those in populations from more industrialized areas of North America and were below thresholds for reproductive impairment. These results provide an essential baseline for future monitoring of the eagle population as industrial development increases in Placentia Bay.

KEY WORDS: *Bald Eagle; Haliaeetus leucocephalus; contaminants; diet; stable isotopes; Newfoundland; productivity.*

EXITO REPRODUCTOR, CONTAMINANTES AMBIENTALES, Y ESTATUS TRÓFICO DE ÁGUILAS CALVAS EN NIDIFICANTES EN EL ESTE DE TERRANOVA (NEWFOUNDLAND), CANADÁ

RESUMEN.—El este de Terranova alberga una gran población residente grande de Águilas Calvas (*Haliaeetus leucocephalus*). Los objetivos de la investigación fueron: determinar el éxito reproductor, los niveles de contaminación, y el estatus trófico de las Águilas Calvas en el este Terranova y comparar los niveles de contaminación de las águilas de bahías costeras industrializadas y no industrializadas (Bahías de Placentia y de Bonavista, respectivamente). La densidad del Águila Calva en reproducción en Terranova oriental fue de 0.09 nidos ocupados/km de costa y el éxito reproductor resultó ser el de una población sana (1.1 juvenil/nido ocupado). La media geométrica de las concentraciones de PCBs y DDE en plasma de polluelos fue significativamenta más alta en la Bahía de Placentia (PCB = 30.0 ng/g [peso fresco]; DDE = 9.0 ng/g) que en la Bahía de Bonavista (PCB = 10.0 ng/g; DDE = 2.0 ng/g).

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En la Bahía de Placentia, se observó una relación inversa entre las concentraciones de PCBs y DDE en polluelos y las distancias desde los nidos a la antigua base naval de los EE.UU. en Argentia. La media geométrica de la concentración de mercurio en la sangre de polluelos fue de 87 ng/g (peso fresco). El análisis de restos de presas recolectadas en los nidos y las proporciones de los isótopos de carbono ($^{13}C/^{12}C$) y nitrógeno ($^{15}N/^{14}N$) en sangre de polluelos, indicaron algunas diferencias entre las fuentes de alimento de los nidos, pero no en el nivel trófico relativo. Los restos de presas recogidos en 30 nidos de Águila Calva estuvieron compuestos por aves (64%), peces (29%) y mamíferos (7%). Los niveles de contaminación en las Águilas Calvas del este de Terranova fueron más bajos que en las de poblaciones de áreas más industrializadas de Norteamérica y se encontraron por debajo del umbral a partir del cual afectan a la reproducción. Estos resultados proporcionan una base esencial para el futuro seguimiento de la población de águilas, a medida que aumente el desarrollo industrial en la Bahía de Placentia.

[Traducción de César Márquezs, Laura Dominguez y Rafael Mateo]

Bald Eagle (*Haliaeetus leucocephalus*) populations were affected seriously throughout North America from the 1950s–1970s by the widespread use of organochlorine pesticides (OCs) such as DDT (Grier 1982, Colborn 1991). Although many breeding populations began recovering in the 1980s–1990s (Grier 1982, Wiemeyer et al. 1993, Bowerman et al. 1995), contaminants still appear to be a limiting factor in the reproductive success of several North American populations (Anthony et al. 1993, 1999, Welch 1994, Bowerman et al. 1995).

One of the densest breeding concentrations of Bald Eagles in eastern North America is in Placentia Bay, Newfoundland (Dominguez 1999). Placentia Bay is also home to several industrial sources of chronic pollution. OC, polychlorinated biphenyl (PCB), and metal pollution was found at the former U.S. naval base in Argentia, which closed in 1994 (JWEL 1996). Fluoride and phosphorus pollution was caused by the phosphorus plant in Long Harbour (Osbourne 1978), which closed in 1989. Other industrial developments in the bay include an oil refinery at Come-By-Chance, a crude oil storage facility at Whiffen Head, a shipyard at Marystown, and associated heavy shipping traffic. Chronic oil pollution in Placentia Bay has been documented by the high incidence of oiled seabirds regularly washing up along its shores (Montevecchi and Tuck 1987, Lock et al. 1994, Wiese and Ryan 2003). Contaminants transported atmospherically or through ocean currents are other possible sources of chronic pollution (Furness 1993, Anthony et al. 1999). A recent study confirmed that PCBs and metals from the former U.S. naval base at Argentia are bioaccumulating in the local marine food web (JWEL 1996). However, there has been no monitoring of contaminant accumulation in top predators, such as Bald Eagles, that are sensitive to the presence of toxic chemicals

that biomagnify up food chains (Howells et al. 1990).

This study was undertaken to assess the reproductive success, contaminant exposure, and trophic status of nesting Bald Eagles prior to further industrial development in Placentia Bay. For comparison, we measured the same parameters in a breeding population of Bald Eagles 80 km to the north in Bonavista Bay, which has had no major industrial development.

We hypothesized that concentrations of PCBs and DDE would be higher in eagle nestlings in Placentia Bay than in Bonavista Bay, and higher in eagle nestlings located closer to the former naval base than in those further away along Placentia Bay. Contaminant concentrations were measured in Bald Eagle nestlings because they are good bioindicators for assessing local contamination over a relatively short period (Welch 1994), and they have been used widely in contaminant monitoring studies across Canada and the United States (Anthony et al. 1993, Bowerman et al. 1995, Elliott and Norstrom 1998, Kumar et al. 2002). The trophic status of nesting Bald Eagles was compared by studying the composition of prey remains at nests and by analyzing stable-carbon and nitrogen isotope ratios in nestling blood samples (Hobson and Montevecchi 1991, Hobson et al. 1994).

METHODS

Placentia Bay, located on the southeastern coast of Newfoundland (Fig. 1), is one of the richest fishing areas in Newfoundland waters, and has important seabird colonies, wintering and staging grounds for millions of seabirds and seaducks, breeding and wintering grounds for Bald Eagles, and feeding areas for several species of marine mammals (LEML and OL 1984, Montevecchi and Tuck 1987, Cairns et al. 1989). Bonavista Bay, located on the northeast coast of Newfoundland (Fig. 1), is also rich in fish, seabird, seaduck, eagle, and marine mammal populations (Deichmann and Bradshaw 1984). The study
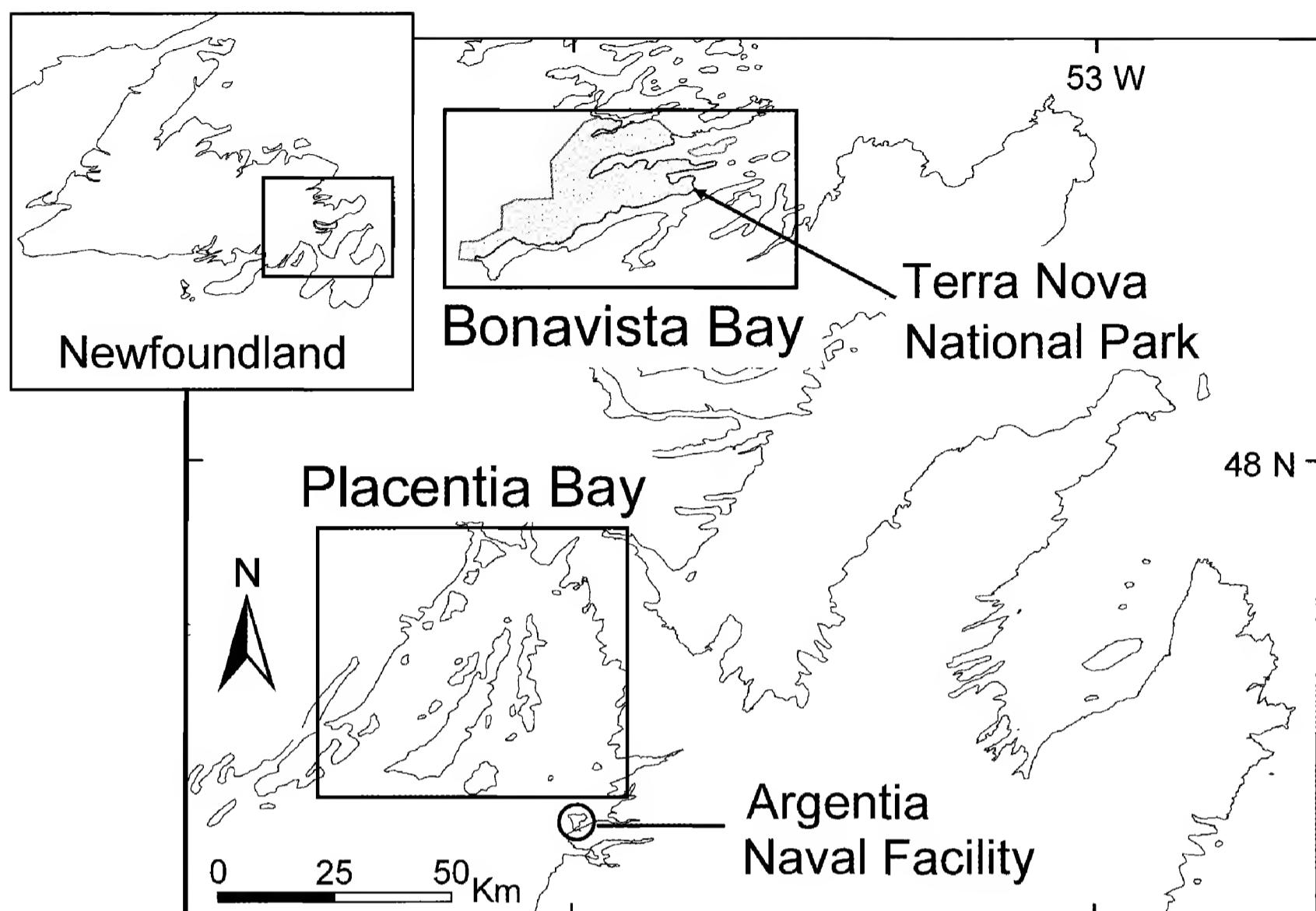
Figure 1.   Location of Bald Eagle study areas in eastern Newfoundland, 1996–97.

area in Bonavista Bay was located within the boundaries of Terra Nova National Park (TNNP).

Reproductive Surveys. We studied Bald Eagle breeding density, nest success, and productivity in Placentia Bay in 1996 and 1997 and in Bonavista Bay in 1997. Definitions of these terms and others used to describe reproductive parameters follow those of Postupalsky (1974) and Kozie and Anderson (1991). We conducted a minimum of two surveys per breeding season along the coastline by aircraft or boat, extending 50–200 m inland from the shoreline, depending on topography. Boat surveys were conducted by cruising at 20–50 m from shore, in a 6-m fiberglass boat at a speed of 10–20 km/hr. Boat surveys in late April–early May assessed breeding population size and nest occupancy. Total shoreline surveyed was measured with MapInfo (MapInfo Corp., Troy, NY) to calculate breeding density (number of occupied nests per kilometer of shoreline). Aerial surveys were conducted by helicopter (Bell 206) in Placentia Bay and by fixed-wing aircraft (Twin Otter) in Bonavista Bay, with cruising speeds of 120–140 km/h and flying altitudes of 50–100 m above tree line. Aerial survey schedules and methodology followed standard methods (Postupalsky 1974, Grier 1982, Fraser et al. 1983). Aerial surveys in early June assessed clutch/brood size and chick development, and nest visits in late June–early July assessed nest success and productivity. Nest visits involved climbing into the nests to collect blood samples from the chicks for contaminant analyses.

Contaminant Analyses. Blood samples from one nestling per nest (Welch 1994) were collected in late June and early July in 1996 and 1997 in Placentia Bay and in 1997 in Bonavista Bay. Approximately 12–15 ml of blood was drawn from the left brachial vein directly into heparinized vacuum tubes when eaglets were 6–8 wk old. From each sample, 4–6 ml of whole blood were frozen in nitric-acid-rinsed cryovials for mercury analysis. The remaining blood was centrifuged and 3–6 ml of plasma were frozen in acetone-hexane-rinsed glass vials for OC analyses. Samples were stored at −20°C until analyzed. Further details on blood collection and processing are provided by Dominguez (1999).

Plasma and whole blood samples were sent to the Canadian Wildlife Service National Wildlife Research Center (NWRC) in Hull, Quebec, for OC and mercury analyses. Measurement of 21 OC pesticides and metabolites and 42 PCB congeners in plasma was conducted by gas-chromatography mass spectrometry (Hewlett Packard model 5890 gas chromatograph, coupled to a Hewlett Packard model 5971 Ni[63] electron capture detector, Palo Alto, CA). Methods follow those of Norstrom and Won (1985). Recoveries of internal standards ranged from 74–104%. Detection limits were 0.1 ng/g wet weight (wet wt) for both OCs and PCBs. Plasma lipids were measured by

Table 1. Reproductive success of Bald Eagle breeding pairs in Placentia and Bonavista Bays, Newfoundland, 1996–97.

LOCATION	YEAR	NO. OCCU-PIED NESTS	NO. SUCCESS-FUL NESTS	NEST SUCCESS (%)	NO. YOUNG/ OCCUPIED NEST	NO. YOUNG/ SUCCESSFUL NEST
Placentia Bay	1996	31	25	81	1.3	1.6
Placentia Bay	1997	27	18	67	0.9	1.4
Bonavista Bay	1997	12	10	83	0.9	1.1

sulpho-phospho-vanillin reaction (Frings et al. 1972). Total mercury in blood was analyzed by cold-vapor atomic-absorption spectrophotometry (Perkin-Elmer 3030-AAS equipped with Varian VGA-76 hydride generator, Shelton, CT; Scheuhammer and Bond 1991, Neugebauer et al 2000). National Research Council of Canada DOLT-2 and DORM-2 were used as standard reference materials to ensure the accuracy of the mercury results. Two blanks were included in each set of digestions. All blood samples were analyzed in duplicate. Recoveries of reference materials were within the certified range. The detection limit for mercury was 40 ng/g (wet wt). Field procedural blanks were included in all chemical analyses. All contaminant concentrations are presented in ng/g (wet wt).

Trophic Analyses. Prey remains and a sample of fine nest material (to check for fish scales and other small remains) were collected from each nest bowl and the nest-site area, and were classified as fish, bird, or mammal. Composition of prey remains is expressed as percent occurrence of minimum number of individuals for each of the three prey classes (Todd et al. 1982, Knight et al. 1990). Regurgitated pellets below nests could not be retrieved because most nests were located on cliffs overhanging the sea. Stable nitrogen isotope ratios ($^{15}N/^{14}N$) were used to compare the dietary trophic level of Bald Eagles between and within study areas (Hobson et al. 1994), and to investigate relationships between contaminant concentrations and trophic level (Braune et al. 2002). Stable carbon isotope ratios ($^{13}C/^{12}C$) were used to investigate food sources (i.e., freshwater vs. marine, benthic vs. pelagic marine food chains; Hobson et al. 1994). Dried blood samples were loaded into tin cups and combusted at 1850°C in a Robo-Prep elemental analyzer (Europa Ltd., Crewe, England) interfaced with a Europa 20:20 continuous-flow isotope-ratio mass spectrometer (Hobson et al. 1999). Two standards (egg albumin) were measured in sequence for every five unknowns. Analytical error is estimated to be ±0.3‰ for ^{15}N and ±0.1‰ for ^{13}C analyses. Stable isotope ratios in blood samples are reported in delta notation as parts per thousand according to the following: δX (‰) = $[(R_{sample}/R_{standard}) - 1] \times 1000$ where X is ^{15}N or ^{13}C and R is the corresponding ratio $^{15}N/^{14}N$ or $^{13}C/^{12}C$. $R_{standard}$ for ^{15}N and ^{13}C are atmospheric N_2 (AIR) and the PDB standard, respectively.

Statistical Analyses. Contaminant data were $\log_{10}$-transformed to achieve a normal distribution, and geometric means were calculated. Contaminant data were not lipid-normalized for statistical analyses because there were no correlations between plasma lipid concentrations and log-transformed concentrations of contaminants (e.g., r

= 0.07, 0.2, and 0.2 for DDE, PCB, and mercury, respectively). When samples had contaminant concentrations below the analytical detection limit, and 50% or more of the samples had values above detection limits, a value of one-half the detection limit was assigned (Anthony et al 1999).

One-way analysis of variance (ANOVA) was used to test differences in the mean contaminant concentrations between years in Placentia Bay, and between Placentia and Bonavista Bays. Within Placentia Bay, relationships between contaminant concentrations in nestling tissues and nest distance (km) to the former U.S. naval base were assessed using linear regression. Differences in composition of prey remains between years in Placentia Bay and between study areas were tested with a chi-square test of independence and Fisher's exact test, respectively. Differences in the means of $\delta^{15}N$ and $\delta^{13}C$ values between study areas were tested with a one-way ANOVA. Linear regression was used to assess relationships between contaminant concentrations and isotopic ratios. Multiple regression analysis was used to assess the relative strength of associations between contaminant concentrations, nest distance to the former naval facility and trophic differences reflected by stable isotope ratios. Randomization tests (Adams and Anthony 1996) were conducted (10 000 runs) to produce reliable P values when residuals from ANOVAs did not show a normal distribution (test results indicated as P_{rand}). A value of $\alpha = 0.05$ was used in all tests. Statistical tests were conducted with Minitab (Minitab Inc., State College, PA) and SYSTAT (SPSS Inc., Chicago, IL).

RESULTS

Reproductive Success. We identified 55 and 13 breeding territories in Placentia and Bonavista Bays, respectively; some of them containing more than one nest. Breeding density was 0.10 and 0.06 occupied nests/km of shoreline for Placentia and Bonavista Bays, respectively (overall mean = 0.09 occupied nests/km). Nest success and productivity (Table 1) were not significantly different between study areas ($\chi^2 = 0.46$, $P = 0.5$ and $F_{1,41} = 2.5$, $P = 0.1$, respectively). Overall, mean nest success in eastern Newfoundland was 76% and mean productivity was 1.1 young/occupied nest.

Organochlorines. Plasma concentrations of OCs were low in all samples in both Placentia and Bon-

avista Bays (Table 2). In Placentia Bay, there were no significant differences in mean concentrations between years (e.g., $F_{1,20} = 0.58$, $P_{rand} = 0.1$ and $F_{1,20} = 1.9$, $P_{rand} = 0.1$ for DDE and PCBs, respectively). Therefore, results were pooled for 1996 and 1997 and mean values were used for nests sampled in both years. Geometric mean concentrations of plasma DDE and PCBs were significantly higher in Placentia Bay than in Bonavista Bay ($F_{1,21} = 4.0$, $P_{rand} = 0.03$ and $F_{1,21} = 6.3$, $P_{rand} = 0.003$, respectively; Table 2). There were no significant differences in mean concentrations of other OCs (Table 2). Dieldrin; pp'-DDD; pp'-DDT; pentachlorobenzene; 1234- and 1245-tetrachlorobenzene; octachlorostyrene; α-, β- and γ-hexachlorocyclohexane; trans-chlordane; and tris(4-chlorophenyl)methanol were detected in less than half of the plasma samples. In Placentia Bay, DDE and PCB concentrations were negatively related to nest distance from the former U.S. naval site at Argentia ($R^2 = 0.4$, $P = 0.07$ and $R^2 = 0.3$, $P = 0.02$, respectively; Fig. 2). There were no significant relationships between concentrations of other OCs and distance from the naval site.

Mercury. No significant differences were found in geometric mean mercury concentrations in whole blood of eagle nestlings between years in Placentia Bay ($F_{1,20} < 0.001$, $P_{rand} = 0.3$), or between Placentia and Bonavista Bays ($F_{1,21} = 1.7$, $P = 0.2$). The overall geometric mean concentration for blood mercury in nestlings in eastern Newfoundland was 87 ng/g ($N = 23$, range: 50–250 ng/g wet wt). There was no association between mercury concentrations and nest distance from the naval base in Placentia Bay (Fig. 2).

Trophic Status. Most birds found in prey remains were Black-legged Kittiwakes (Rissa tridactyla), and Herring Gulls (Larus argentatus), or murres (Uria spp.) in both Placentia and Bonavista Bays. Fish species included yellow-tail flounder (Limanda ferruginea), wolffish (Anarhichas spp.), sculpin (Myoxocephalus spp.), lumpfish (Cyclopterus lumpus), Atlantic cod (Gadus morhua), redfish (Sebastes spp.), Atlantic herring (Clupea harengus), and American lobster (Homarus americanus). The only mammal remains identified were snowshoe hare (Lepus americanus). The minimum percent occurrence of avian, fish, and mammalian prey in the remains at 22 Placentia Bay eagle nests and eight Bonavista Bay nests averaged 64, 29, and 7%, respectively. There were no significant differences in the frequency of occurrence of bird and fish re-

Table 2. Geometric mean concentrations of organochlorines[a] (ng/g, wet wt) and percent lipids in plasma of Bald Eagle nestlings from Placentia and Bonavista Bays, Newfoundland, 1996–97. Ranges of plasma concentrations are indicated in parentheses.

LOCATION	YEAR	TISSUE	N	% LIPID	ΣPCB	p,p'-DDE	t-NON-ACHLOR	HCB	OXY-CHLOR-DANE	Cis-NON-ACHLOR	Cis-CHLORDANE	MIREX	PHOTO-MIREX	HE
Placentia	96–97	plasma	17	0.79	36 A[b]	8.6 B[b]	1.9	1.0	1.0	0.4	0.3	0.3	0.3	0.3
				(0.65–0.96)	(11–133)	(2.0–41)	(0.8–3.9)	(0.5–3.0)	(0.3–3.6)	(ND[c]–0.8)	(ND–0.9)	(ND–2.5)	(ND–1.2)	(ND–1.1)
Bonavista	97	plasma	6	0.87	14 A	1.9 B	1.6	0.7	0.5	0.4	0.4	ND	0.3	0.1
				(0.71–1.21)	(8.0–35)	(0.4–5.8)	(0.9–2.8)	(0.5–1.3)	(0.2–1.3)	(0.3–0.7)	(0.3–0.5)	(ND–0.3)	(ND–1.0)	(ND–0.4)

[a] Abbreviations are as follows: ΣPCB = sum of 42 PCB congeners, t-nonachlor = trans-nonachlor, HCB = hexachlorobenzene, HE = heptachlor epoxide.
[b] A, B = means sharing the same letter are significantly different, $P_{rand} < 0.05$.
[c] ND = below detection limit (0.1 ng/g, wet wt).
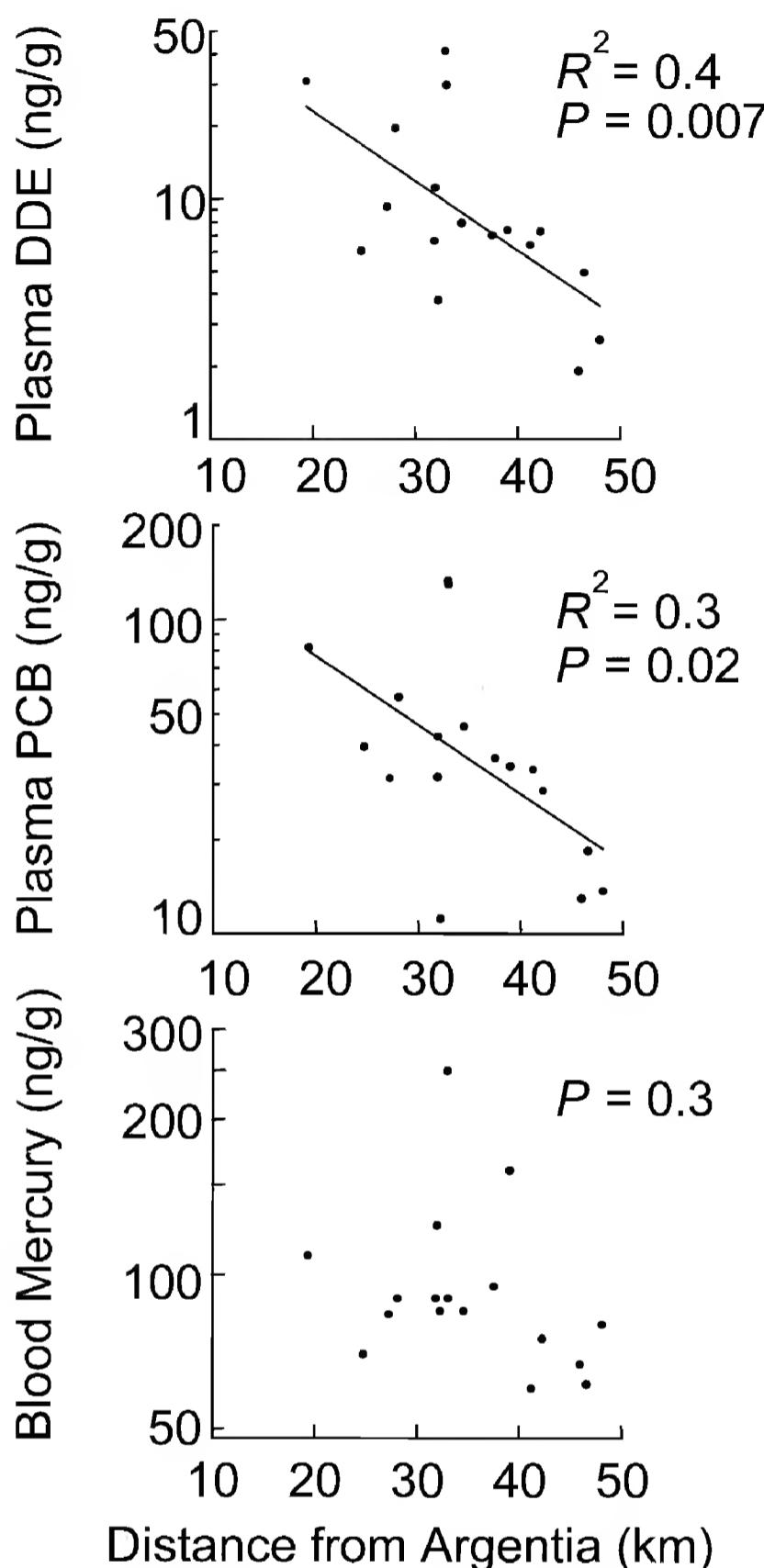
Figure 2. Regressions of contaminant concentrations (ng/g, wet wt) in plasma or whole blood of Bald Eagle nestlings in Placentia Bay and nest distance (km) from the former U.S. naval base at Argentia, Newfoundland.

mains either between years in Placentia Bay (N = 80, χ^2 = 0.1, P = 0.2) or between Placentia and Bonavista Bays (N = 102, χ^2 = 0.9, P = 0.3).

Stable isotope ratios were determined in 13 blood samples from Placentia Bay and six samples from Bonavista Bay collected in 1997. Geometric mean $\delta^{15}N$ values ($\pm SD$) in nestling blood were

not significantly different between Placentia and Bonavista Bays (16.0 $\pm$ 0.4‰ and 15.7 $\pm$ 0.2‰, respectively; $F_{1,17}$ = 1.69, P = 0.2). $\delta^{15}N$ values were not significantly related to plasma DDE concentrations (R^2 = 0.004, $F_{1,15}$ = 0.44, P = 0.5), plasma PCB concentrations (R^2 = 0.002, $F_{1,15}$ = 0.03, P = 0.8), blood mercury concentrations (R^2 = 0.002, $F_{1,15}$ = 0.02, P = 0.9), or nest distance from the naval site in Placentia Bay (R^2 = 0.03, $F_{1,11}$ = 0.2, P = 0.6). Geometric mean $\delta^{13}C$ values ($\pm SD$) in nestling blood were greater in Bonavista Bay than in Placentia Bay (−17.8 $\pm$ 0.2‰ and −18.3 $\pm$ 0.5‰, respectively; $F_{1,17}$ = 5.0, P = 0.05). $\delta^{13}C$ values were negatively associated with plasma DDE (R^2 = 0.36, $F_{1,15}$ = 9.3, P = 0.008) and PCB concentrations (R^2 = 0.36, $F_{1,15}$ = 8.7, P = 0.009) in nestlings from both bays. There was no relationship between $\delta^{13}C$ values and blood mercury concentrations (R^2 = −0.09, $F_{1,15}$ = 2.1, P = 0.2). Within Placentia Bay, $\delta^{13}C$ values were positively related to nest distance from the naval base (R^2 = 0.48; $F_{1,9}$ = 8.3; P = 0.02).

Multiple regression results indicated that plasma DDE concentrations in Placentia Bay eagles were associated with nest distance from the naval base but not with $\delta^{13}C$ values (R^2 = 0.66, $F_{1,8}$ = 10.5, P = 0.01; $F_{1,8}$ = 0.4, P = 0.5; respectively). Similar analysis showed that plasma PCB concentrations were associated more with nest distance from the naval base than with $\delta^{13}C$ values, although neither association was statistically significant (R^2 = 0.46, $F_{1,8}$ = 3.4, P = 0.1; $F_{1,8}$ = 0.001, P = 0.9; respectively) for Placentia Bay nestlings.

DISCUSSION

Concentrations of OCs in plasma of Bald Eagle nestlings were low in both study areas in eastern Newfoundland. Observed plasma DDE and PCB concentrations were below thresholds associated with depressed Bald Eagle productivity (i.e., <0.7 young/occupied nest), namely 107 ng/g PCBs and 26 ng/g DDE (Bowerman et al. 1995). Levels of DDE, PCBs, and other OCs were lower than those found in plasma of nestling eagles in more industrialized regions such as the Columbia River Estuary, Great Lakes, and Maine (geometric means: 80–200 ng/g PCB, 20–100 ng/g DDE; Anthony et al. 1993, Bowerman 1993, Matz 1998, Donaldson et al. 1999) but were similar to those found in British Columbia and interior areas of the Midwest and Ontario (5–50 ng/g PCB, 3–24 ng/g DDE; Bowerman 1993, Elliott 1995, Donaldson et al. 1999). We

conclude that OC concentrations in eagle nestlings in eastern Newfoundland are below levels associated with population-level impacts.

Mean DDE and PCB concentrations were significantly higher in Placentia Bay than in Bonavista Bay, with an increasing trend in Placentia Bay in nests closer to the Argentia naval base. Concentrations of other OCs were similar in both study areas. Our findings support the hypotheses that the Argentia naval base is a source of PCB contamination to the local marine environment, and that part of the contamination detected in the eagles had a local origin at the base (although we acknowledge the smaller sample size from the reference site in our comparative analyses). The U.S. Navy constructed the Naval Air Station, Dockyard, and associated fuel, ordnance, communication, and support facilities at Argentia in the early 1940s (Argentia Remediation Group 1995). These facilities were gradually closed or abandoned by the American military between 1968 and 1994. Soil, groundwater, marine sediments, and biota at Argentia were contaminated with petroleum hydrocarbons, OCs, PCBs, or metals, which leaked from fuel storage tanks, an electrical power plant, electrical transformers, several landfills, and equipment storage areas (Argentia Remediation Group 1995, JWEL 1996). Our results suggest that PCB contamination of marine fish observed around Argentia (JWEL 1996) is moving up the food web into Bald Eagles (although not reaching toxic concentrations in eagle nestlings).

PCB contamination has been frequently observed around military installations in North America, Europe, and Asia (de March et al. 1998, Gregor et al. 2003, Kuzyk et al. 2003). At these contaminated sites, PCBs are often found in soil adjacent to buildings with electrical equipment, in and around dumps, and migrating from these sources down drainage channels into the ocean (Gregor et al. 2003). In a contaminant study in the Aleutian Islands of Alaska, Anthony et al. (1999) reported higher levels of PCBs in Bald Eagle eggs from nests that were located on islands that had a former military base than in eggs from islands that did not.

Blood mercury levels in Newfoundland Bald Eagle nestlings were similar to those in Florida and coastal Maine nestlings (geometric means: 82–130 ng/g; Welch 1994, Wood et al. 1995), but lower than those in Oregon and Washington nestlings (230–1200 ng/g; Wiemeyer et al. 1989, Anthony et al. 1993). No threshold value for adverse effects is available in the literature for blood mercury concentrations in Bald Eagles. The blood mercury concentrations in Newfoundland eagles were less than those (ca. 1000 ng/g in 5-wk-old chicks) that led to sublethal effects on appetite, body condition, behavioral activity, anemia, and organ histology in dosed Great Egrets (*Ardea alba*) (Bouton et al. 1999, Spalding et al. 2000a, 2000b).

Dietary habits and trophic level can influence contaminant concentrations in eagles. Bald Eagles that feed mainly on seabirds, especially gulls, are known to bioaccumulate higher concentrations of contaminants than eagles feeding mainly on fish or terrestrial herbivores (Kozie and Anderson 1991, Welch 1994, Anthony et al. 1999). Our analysis of bird, fish, and mammal remains at eagle nests indicated that the trophic status of eagles was similar in Placentia and Bonavista Bays. Prey remains collected at Newfoundland nests were similar to other coastal populations of Bald Eagles, where seabirds predominate in the diet (Welch 1994, Todd et al. 1982, Knight et al. 1990). Because analysis of Bald Eagle prey remains overestimates the dietary importance of birds, medium-sized mammals, and bony fish, while underestimating consumption of small fish and mammals (Mersmann et al. 1992), it is important to limit comparisons to similar studies of prey remains.

Traditionally, combined analyses of prey remains, regurgitated pellets, and direct observation of feeding events are required to assess dietary composition accurately for Bald Eagles (Mersmann et al. 1992). However, stable isotopic analyses of bird tissues is another method available to quantitatively assess their trophic status (Hobson et al. 1994). Analyses of $\delta^{15}N$ values in nestling blood samples showed no dietary trophic differences among nestlings, and no relationships between contaminants and $\delta^{15}N$ values. Although $\delta^{15}N$ values of food web components may differ among locations, we feel that the observed differences in contaminant levels are not due to differences in dietary trophic level among nestlings. This conclusion is supported by the prey remains analysis.

In contrast, $\delta^{13}C$ values were greater in Bonavista Bay, and in nests further away from the Argentia naval base in Placentia Bay. Greater $\delta^{13}C$ ratios in birds in marine ecosystems have been related to diets with more inshore or benthic prey, while lower $\delta^{13}C$ ratios have been related to more offshore and pelagic-based diets (Hobson et al. 1994). Nests in Bonavista Bay are located in a long sound with

an estuary at the head of the bay. In Placentia Bay, nests further away from the naval base are also located near an estuary at the head of the bay, while nests closer to the base are located on islands nearer the mouth of the bay. This difference in geographical distribution and proximity to freshwater inputs could explain the differences in $\delta^{13}C$ values between study sites and within Placentia Bay. The associations found between $\delta^{13}C$ values and PCB and DDE levels in nestling plasma indicate a possible dietary cause for differences in contaminant concentrations. However, the multiple regression analysis suggests that proximity to the Argentia naval base was more important than $\delta^{13}C$ values in influencing DDE and PCB concentrations in young eagles. Given our small sample sizes, the snap-shot nature of our dietary study, the opportunistic foraging strategies of Bald Eagles (Stalmaster 1987), and the changing availability of different prey through the breeding season (e.g., spawning of different species of fish), there remains much to investigate about Bald Eagle foraging ecology, stable isotope patterns, and their association with contaminant levels in Newfoundland.

Breeding density of Bald Eagles in eastern Newfoundland (0.090 occupied nests/km shoreline) was similar to coastal British Columbia (0.086 nests/km; Hodges and King 1984), greater than coastal New Brunswick (0.014 nests/km; Stocek and Pearce 1981) and Nova Scotia (0.047 nests/km; MacDonald and Austin-Smith 1989), but less than the maximum densities seen along the southeast coast of Alaska (0.28 nests/km; Hodges 1982). High breeding densities and reproductive output of Bald Eagles in marine ecosystems are often associated with high quality and availability of nesting habitat and with food abundance (Hansen 1987).

We cannot draw a definitive conclusion on the reproductive status of the Bald Eagle population in eastern Newfoundland from our study because a minimum of 3 yr of data collection is recommended to reliably determine mean productivity (Elliott 1995). However, our data from the two years in Placentia Bay and the one year in Bonavista Bay indicate that reproductive success was high and are suggestive of a healthy breeding population, i.e., >1 young/occupied nest (Wiemeyer et al. 1993, Bowerman et al. 1995). The breeding densities and reproductive success of Bald Eagles in eastern Newfoundland can presumably be attributed to high availability and quality of food, perches, and nest-

ing habitat (Chandler et al. 1995), and to relatively low contaminant levels in the environment.

We found no evidence that current contaminant levels are impairing reproduction in Bald Eagles in Placentia and Bonavista Bays. Nevertheless, Bald Eagles would be an excellent bioindicator of any ecological impacts of future industrial development in Placentia Bay (e.g., proposed nickel smelter at Argentia), and of any ecological benefits of on-going remediation of existing contaminated sites at Argentia. This study provides the necessary baseline information on Bald Eagle productivity and contamination for any future monitoring program.

LITERATURE CITED

ADAMS, D.C. AND C.D. ANTHONY. 1996. Using randomization techniques to analyze behavioral data. *Anim Behav.* 51:733–38.

ANTHONY, R.G., M.G. GARRET, AND C.A. SCHULER. 1993. Environmental contaminants in Bald Eagles in the Columbia River Estuary. *J. Wildl. Manage.* 57:10–19.

———, A.K. MILES, J.A. ESTES, AND F.B. ISAACS. 1999. Productivity, diets, and environmental contaminants in nesting Bald Eagles from the Aleutian Archipelago *Environ. Toxicol. Chem.* 18:2054–2062.

ARGENTIA REMEDIATION GROUP. 1995. Phase III/phase IV environmental site assessment, US Naval Facility Argentia, Newfoundland: Report 2, site characterization. Report No. 20000-413. Argentia Remediation Group, Dartmouth, NS Canada.

BOUTON, S.N., P.C. FREDERICK, M.G. SPALDING, AND H McGILL. 1999. Effects of chronic, low concentrations of dietary methylmercury on the behavior of juvenile great egrets. *Environ. Toxicol. Chem.* 18:1934–1939.

BOWERMAN, W.W. 1993. Regulation of Bald Eagle (*Ha-*

liaeetus leucocephalus) productivity in the Great Lakes Basin: an ecological and toxicological approach. Ph.D. dissertation, Michigan State University, East Lansing, MI U.S.A.

———, J.P. GIESY, D.A. BEST, AND V.J. KRAMER. 1995. A review of factors affecting productivity of Bald Eagles in the Great Lakes region: implications for recovery. Environ. Health Perspect. 103(Suppl. 4):51–59.

BRAUNE, B.M., G.M. DONALDSON, AND K.A. HOBSON. 2002. Contaminant residues in seabird eggs from the Canadian Arctic: II spatial trends and evidence from stable isotopes for intercolony differences. Environ. Pollut. 117:133–145.

CAIRNS, D.K., W.A. MONTEVECCHI, AND W. THRELFALL. 1989. Researcher's guide to Newfoundland seabird colonies, 2nd Ed. Memorial Univ. Nfld. Occas. Pap. Biol. 14.

CHANDLER, S.K., J.D. FRASER, D.A. BUEHLER, AND J.K.D. SEEGAR. 1995. Perch trees and shoreline development as predictors of Bald Eagle distribution on Chesapeake Bay. J. Wildl. Manage. 59:325–332.

COLBORN, T. 1991. Epidemiology of Great Lakes Bald Eagles. J. Toxicol. Environ. Health 33:395–453.

DEICHMANN, K.H. AND D.B. BRADSHAW. 1984. Terra Nova National Park: resource description and evaluation. Parks Canada, Glovertown, NF Canada.

DE MARCH, B.G.E., C.A. DE WIT, AND D.C.G. MUIR. 1998. Persistent organic pollutants. Pages 183–371 in S.J. Wilson, J.L. Murray, and H.P. Huntington [EDS.], AMAP assessment report: Arctic pollution issues. Arctic Monitoring and Assessment Programme, Oslo, Norway.

DOMINGUEZ, L. 1999. Reproductive success and environmental contaminants among Bald Eagles in Placentia and Bonavista Bays, Newfoundland. M.S. thesis, Memorial University of Newfoundland, St. John's, NF Canada.

DONALDSON, G.M., J.L. SHUTT, AND P. HUNTER. 1999. Organochlorine contamination in Bald Eagle eggs and nestlings from the Canadian Great Lakes. Arch. Environ. Contam. Toxicol. 36:70–80.

ELLIOTT, J.E. 1995. Environmental contaminants in Bald Eagles on the coast of British Columbia: exposure and biological effects. Ph.D. dissertation, University of British Columbia, Vancouver, BC Canada.

——— AND R.J. NORSTROM. 1998. Chlorinated hydrocarbon contaminants and productivity of Bald Eagle populations on the Pacific Coast of Canada. Environ. Toxicol. Chem. 17:1142–1153.

FRASER, J.D., I.D. FRENZEL, J.E. MATHISEN, F. MARTIN, AND M.E. SHOUGH. 1983. Scheduling Bald Eagle reproductive surveys. Wildl. Soc. Bull. 11:13–16.

FRINGS, C.S., T.W. FENDLEY, R.T. DUNN, AND C.A. QUENN. 1972. Improved determination of total serum lipids by the sulpho-phospho-vanillin reaction. Clin. Chem. 18:673–674.

FURNESS, R.W. 1993. Birds as monitors of pollutants. Pag-

es 86–143 in R.W. Furness and J.J.D. Greenwood [EDS.], Birds as monitors of environmental change Chapman & Hall, New York, NY U.S.A.

GREGOR, D., J. STOW, D. KENNEDY, K. REIMER, AND C. OLLSON. 2003. Local sources of contaminants in the Canadian Arctic. Pages 158–183 in T. Bidleman, R. Macdonald, and J. Stow [EDS.], Canadian Arctic Contaminants Assessment Report II: sources, occurrence, trends and pathways in the physical environment. Indian & Northern Affairs Canada, Ottawa ON Canada.

GRIER, J.W. 1982. Ban of DDT and subsequent recovery of reproduction in Bald Eagles. Science 218:1232–1235.

HANSEN, A.J. 1987. Regulation of Bald Eagle reproductive rates in southeastern Alaska. Ecology 68:1387–1392.

HOBSON, K.A. AND W.A. MONTEVECCHI. 1991. Stable isotopic determinations of trophic relationships of Great Auks. Oecologia 87:527–531.

———, J.F. PIATT, AND J. PITOCCHELLI. 1994. Using stable isotopes to determine seabird trophic relationships J Anim. Ecol. 63:786–798.

———, M. DREVER, AND G. KAISER. 1999. Norway rats as predators of burrow-nesting seabirds: insights from stable isotope analysis. J. Wildl. Manage. 63:14–25.

HODGES, J.I., JR. 1982. Bald Eagle nesting studies in Seymour Canal, southeast Alaska. Condor 84:125–127.

——— AND J.G. KING. 1984. Bald Eagle breeding population survey of coastal British Columbia. J. Wildl Manage. 48:993–998.

HOWELLS, D., D. CALAMARI, J. GRAY, AND P.G. WELLS. 1990. An analytical approach to assessment of long-term effects of low levels of contaminants in the marine environment. Mar. Pollut. Bull. 21:371–375.

JWEL. 1996. Marine sampling off landfill 1, former United States naval facility, Argentia, Newfoundland JWEL Report No. 84336. Jacques Whitford Environment Ltd., St. John's, NF Canada.

KNIGHT, R.L., P.J. RANDOLPH, G.T. ALLEN, L.S. YOUNG, AND R.J. WIGEN. 1990. Diets of nesting Bald Eagles, Haliaeetus leucocephalus, in western Washington. Can Field-Nat. 104:545–551.

KOZIE, K.D. AND R.K. ANDERSON. 1991. Productivity, diet, and environmental contaminants in Bald Eagles nesting near the Wisconsin shoreline of Lake Superior Arch. Environ. Contam. Toxicol. 20:41–48.

KUMAR, K.S., K. KANNAN, J.P. GIESY, AND S. MASUNAGA 2002. Distribution and elimination of polychlorinated dibenzo-p-dioxins, dibenzofurans, biphenyls, and p,p'-DDE in tissues of Bald Eagles from the Upper Peninsula of Michigan. Environ. Sci. Technol. 36:2789–2796.

KUZYK, Z.A., N.M. BURGESS, J.P. STOW, AND G.A. FOX. 2003. Biological effects of marine PCB contamination on black guillemot nestlings at Saglek, Labrador: liver biomarkers. Ecotoxicology 12:183–197.

LEDREW ENVIRONMENTAL MANAGEMENT LTD. AND OCEANS

LTD. 1984. Southeastern Newfoundland marine resources: a literature review. Newfoundland and Labrador Dept. of Development, St. John's NF Canada.

LOCK, A.R., R.G.B. BROWN, AND S.H. GERRIETS. 1994. Gazetteer of marine birds in Atlantic Canada: an atlas of seabird vulnerability to oil pollution. Canadian Wildlife Service, Dartmouth, NS Canada.

MACDONALD, P.R.N. AND P.J. AUSTIN-SMITH. 1989. Bald Eagle, *Haliaeetus leucocephalus,* nest distribution on Cape Breton Island, Nova Scotia. *Can. Field-Nat.* 103: 293–296.

MATZ, A.C. 1998. Organochlorine contaminants and Bald Eagles *Haliaeetus leucocephalus* in Maine: investigations at three ecological scales. Ph.D. dissertation, University of Maine, Orono, ME U.S.A.

MERSMANN, T.J., D.A. BUEHLER, J.D. FRASER, AND J.K.D. SEEGAR. 1992. Assessing bias in studies of Bald Eagle food habits. *J. Wildl. Manage.* 56:73–78.

MONTEVECCHI, W.A. AND L.M. TUCK. 1987. Newfoundland birds: exploitation, study, conservation. *Publ. Nuttall Ornithol. Club* 21, Cambridge, MA U.S.A.

NEUGEBAUER, E.A., G.L. SANS CARTIER, AND B.J. WAKEFORD. 2000. Methods for the determination of metals in wildlife tissues using various atomic absorption spectrophotometry techniques. *Can. Wildl. Serv. Tech. Rep.* 337.

NORSTROM, R.J. AND H.T. WON. 1985. Long term preservation of egg and tissue homogenates for the determination of organochlorine compounds: freezing versus freeze drying. *J. Assoc. Off. Anal. Chem.* 68:129–135.

OSBORNE, J.M. 1978. Invertebrate diversity Long Harbour, Placentia Bay, Nfld.: eight years after a pollution crisis. Surveillance Report EPS 5-AR-78-2, Environment Protection Service, Environment Canada, Atlantic Region, St. John's, NF Canada.

POSTUPALSKY, S. 1974. Raptor reproductive success: some problems with methods, criteria, and terminology. *Raptor Res. Rep.* 2:21–31.

SCHEUHAMMER, A.M. AND D. BOND. 1991. Factors affecting the determination of total mercury in biological samples by continuous flow cold vapour atomic absorption spectrophotometry. *Biolog. Trace Element Res.* 31:119–129.

SPALDING, M.G., P.C. FREDERICK, H.C. McGILL, S.N. BOUTON, AND L.R. McDOWELL. 2000a. Methylmercury accumulation in tissues and its effects on growth and appetite in captive great egrets. *J. Wildl. Dis.* 36:411–422.

———, ———, ———, ———, L.J. RICHEY, I.M. SCHUMACHER, C.G.M. BLACKMORE, AND J. HARRISON. 2000b. Histologic, neurologic, and immunologic effects of methylmercury in captive great egrets. *J. Wildl. Dis.* 36: 423–435.

STALMASTER, M.V. 1987. The Bald Eagle. Universe Books, New York, NY U.S.A.

STOCEK, R.F. AND P.A. PEARCE. 1981. Status and breeding success of New Brunswick Bald Eagles. *Can. Field-Nat.* 95:428–433.

TODD, C.S., L.S. YOUNG, R.B. OWEN, AND F.J. GRAMLICH. 1982. Food habits of Bald Eagles in Maine. *J. Wildl. Manage.* 46:636–645.

WELCH, L.J. 1994. Contaminant burdens and reproductive rates of Bald Eagles breeding in Maine. M.S. thesis, University of Maine, Orono, ME U.S.A.

WIEMEYER, S.N., R.W. FRENZEL, R.G. ANTHONY, B.R. McCLELLAND, AND R.L. KNIGHT. 1989. Environmental contaminants in blood of western Bald Eagles. *J. Raptor Res.* 23:140–146.

———, C.M. BUNCK, AND C.J. STAFFORD. 1993. Environmental contaminants in Bald Eagle eggs (1980–84) and further interpretations of relationships to productivity and shell thickness. *Arch. Environ. Contam. Toxicol.* 24: 213–227.

WIESE, F.K. AND P.C. RYAN. 2003. The extent of chronic marine oil pollution in southeastern Newfoundland waters assessed through beached-bird surveys 1984–1999. *Mar. Pollut. Bull.* 46:(in press).

WOOD, P.B., J.H. WHITE, A. STEFFER, J.M. WOOD, C.F. FACEMIRE, AND H.F. PERCIVAL. 1995. Mercury concentrations in tissues of Florida Bald Eagles. *J. Wildl. Manage.* 60: 178–185.

HABITAT AND NEST-SITE USE BY RED-TAILED HAWKS IN NORTHWESTERN WYOMING

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ABSTRACT.—We described Red-tailed Hawk (*Buteo jamaicensis*) habitat in the valley portion of Grand Teton National Park during 1992–94 at three spatial scales: (1) nest tree, (2) microhabitat centered around nest trees, and (3) within the home range. Nests were found in six tree species, 22 (36%) were in coniferous and 38 (64%) were in deciduous trees. Nest-tree height, nest height, nest-tree diameter-at-breast-height (DBH), and percentage height of nest in the tree means were 22 m, 16 m, 50 cm, and 72.7%, respectively. Nests were located predominantly on northwestern aspects and on moderately-steep slopes. Microhabitat selection was determined by comparing nest sites with randomly-located, non-nest sites. We measured nest-site microhabitat characteristics in 0.04-ha circles centered on nest trees and two paired non-nest sites at 60 independent locations. Compared to non-nest sites, nest-sites had a higher number of trees, taller trees, larger DBH and basal area of trees, and greater canopy cover. Among nest sites, 50 of 60 nest trees were the tallest trees in the plot, and 48 of 60 had the largest diameter. Discriminant function analysis indicated that canopy cover, basal area of trees, and distance to forest edge were the most important variables in distinguishing nest sites from non-nest sites. We calculated cover of six vegetation classes within 100% minimum convex polygon home ranges of seven breeding Red-tailed Hawk pairs, and within a 10 640 ha core study area. The proportion of habitat cover types in home ranges varied considerably among individual pairs. Among all home ranges, 75% were non-forested open grassland or shrub and 25% were forested. Habitat characteristics important to Red-tailed Hawks on our study area were mature forests of mixed conifer and deciduous trees on moderately-steep hillsides adjacent to expansive openings consisting of either sagebrush (*Artemisia* spp.)-grassland flats or remnant agricultural sites. Landscape-scale factors other than vegetation cover-type proportions may be more important in determining home range size and location within our study area.

KEY WORDS: *Red-tailed Hawk; Buteo jamaicensis; nesting habitat; habitat use; home range; Grand Teton National Park; Wyoming.*

HABITAT Y USO DEL SITIO DEL NIDO DEL GAVILAN DE COLA ROJA EN EL NOROESTE DE WYOMING

RESUMEN.—Describimos el hábitat del gavilán de Cola Roja (*Buteo jamaicensis*) en el valle del Grand Teton National Park durante 1992–94, en tres escalas espaciales: (1) árbol con nido, (2) microhábitat

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centrado alrededor de árboles con nidos y (3) dentro del rango ocupación. Se encontraron nidos en seis especies de árboles, 22 (36%) fueron en coníferas y 38 (64%) fueron en árboles deciduos. La altura del árbol con nido, la altura del nido, el diámetro a la altura del pecho (DAP) del árbol con nido y el porcentaje de la altura del nido de las medias de los árboles fueron 22 m, 16 m, 50 cm, y 72.7%, respectivamente. Los nidos se localizaron predominantemente en vertientes del noroeste y en pendientes moderadamente empinadas. La selección de micro hábitats se determinó comparando los sitios que tenían nidos, con sitios sin nidos localizados al azar. Se midieron características de los micro hábitats, de los sitios con nido, en círculos de 0.04 ha con centro en los árboles con nido y dos sitios pareados sin nidos en 60 lugares independientes. Al comparar los sitios sin nidos, con los sitios con nido, estos ultimos tuvieron un número más alto de árboles, árboles más altos, DAP y área basal de árboles más grandes, y mayor cobertura del dosel. Entre los sitios con nidos, 50 de 60 árboles con nido fueron los árboles más altos en el cuadrante y 48 de 60 tuvieron el diámetro más grande. El análisis de la función de discriminación indicó que la cobertura del dosel, el área basal de los árboles y la distancia al borde del bosque fueron las variables más importantes para distinguir los sitios con nido de los sitios sin nido. Se calculó la cobertura de seis clases de vegetación dentro del 100% del polígono convexo mínimo del rango de ocupación de 7 parejas del gavilán de cola roja en reproducción dentro de un área de estudio de 10 640 ha. La proporción de los tipos de cobertura de hábitat en los rangos de ocupación, variaron considerablemente entre parejas. Entre todos los rangos de ocupación, el 75% fueron praderas abiertas sin árboles o arbustos y 25% fueron praderas sin árboles. Las características de los hábitat importantes para los gavilanes de cola roja en el área del estudio, fueron bosques maduros con coníferas y árboles deciduos en laderas moderadamente empinadas, adyacentes a regiones ampliamente pobladas con *Artemisia* spp., pastizales o remanentes de regiones agrícolas. Otros factores de la escala del paisaje además de las proporciones del tipo de cobertura de la vegetación podrían ser más importantes para determinar el tamaño del rango de ocupación y la ubicación dentro del área del estudio.

[Tradducción de César Márquez]

Red-tailed Hawks (*Buteo jamaicensis*) are widely distributed in North America and breed and winter in a wide variety of habitats (Bent 1937, Palmer 1988, Preston and Beane 1993). Previous studies have quantified Red-tailed Hawk habitat use at multiple scales, including perch sites (Preston 1980), nest-tree sites (Mader 1978, Titus and Moser 1981, Bednarz and Dinsmore 1982, Speiser and Bosakowski 1988), on a landscape level (Stout et al. 1998), and within nesting (Janes 1984), and over wintering (Preston 1990) territories. Little is known, however, about Red-tailed Hawk habitat use in the intermountain region of the western United States. During 1990 and 1991 we monitored raptor and Common Raven (*Corvus corax*) productivity along the floodplain forests of the Snake River and its tributaries in Grand Teton National Park (GTNP). During those two years, we recorded zero fledglings from 12 Red-tailed Hawk nests. We also documented a high density of breeding Common Ravens, whose breeding populations had increased dramatically since the 1940s (Dunk et al. 1994). In addition, during 1990–91, we periodically found dead hawk chicks below nests. We thus began a broad-based ecological study of Red-tailed Hawks in northwestern Wyoming designed to investigate the causes of low productivity. In par-

ticular we evaluated the effects of parasites on Red-tailed Hawk reproduction (Smith et al. 1998) as well as evaluating breeding habitat use patterns of both Common Ravens (Dunk et al. 1997) and Red-tailed Hawks. Herein, we describe our findings of the associations of Red-tailed Hawks to vegetation at three spatial scales: (1) the nest tree, (2) microhabitat within 0.04 ha vegetation plots centered around nest trees, and (3) within the home range.

STUDY AREA

The study area was located in northwestern Wyoming within the valley portion of GTNP (43°40'N, 110°43'W), a high mountain valley that is surrounded by the Teton Mountain Range to the west, the Gros Ventre Mountains to the east, the Yellowstone Plateau to the north, and the town of Jackson to the south. We conducted home range analyses within a 10 640 ha core study area that included Moose, Blacktail Butte, and east to the foothills of Shadow Mountain. Vegetation, climate, and landscape features within the study area have been described by Craighead and Craighead (1956), Dunk et al. (1997), and Smith et al. (1998). Elevation of nests within the study area ranged from 1934–2164 m ($N = 74$).

METHODS

The study was conducted from March 1992 to August 1994. Nests were located in April and May by systematic annual searches of the core study area and surrounding areas. Terminology used in this study follow recommendations by Postupalsky (1974) and Steenhof and Kochert

Table 1. Structural habitat variables measured in 0.04 ha vegetation plots centered on nest trees and at randomly-located non-nest plots.

HABITAT VARIABLE	DESCRIPTION
Nest tree spp	Species of nest tree
Nest height	Height of nest tree (m), measured with a clinometer
Nest DBH	Diameter at breast height of nest tree (cm)
Percent nest height	Height of nest in tree divided by nest-tree height × 100
Number trees	Total number of trees in plot, measured with a clinometer
Tree height	Height of trees in plot, including nest trees, measured with a clinometer
Canopy cover[a]	Percent canopy closure in the plot
Ground cover[a]	Percent ground cover in the plot
Shrub cover[a]	Percent shrub cover in the plot
Distance to edge	Distance from plot center to nearest forest opening
Foliage ht 0–0.3 m[b]	Understory foliage density height 1 (0–0.3 m)
Foliage ht 0.3–3 m[c]	Understory foliage density heights 2–4 combined (0.3–3 m)
Basal area	Basal area of all trees in plot
Slope	Slope of plot, measured with clinometer (degrees)
Aspect	Direction of slope, measured with compass

[a] Eight transects 45° apart were walked, stopping every 2 m. At each stop we sighted directly above and below through an ocular sighting tube with cross hairs at one end and recorded presence or absence of vegetation.

[b] Modified understory foliage density estimated at four levels with a drop cloth (Noon 1981) placed at the edge of the plot in each of four cardinal directions.

[c] Density heights 2–4 did not differ significantly; thus, we used the mean of layer 2–4 combined.

(1982). An occupied nest refers to a nest where: (1) eggs were laid, or young were raised; (2) we saw fresh green boughs on the nest rim or in the nest with adult hawks present; (3) two adults observed in the nest, either perched or actively maintaining the nest; (4) an adult in incubation posture in the nest. All habitat data were collected from occupied nests and the territories they were within.

Nest Tree and Microhabitat Characteristics. We measured five nest-tree variables and 12 structural-habitat variables (Table 1) at nest sites at least two weeks after fledging and before drying of understory vegetation. We defined the nest site as the 11.3-m radius (0.04 ha) circle centered on the nest tree (Noon 1981). For each nest site, we located two non-nest sites in a random compass direction and distance 25–200 m from the nest and measured the same 12 structural habitat variables (Table 1). We maintained that a non-nest site located within 200 m from the nest was within a Red-tailed Hawk territory and thus was available to a nesting pair. We calculated means for each pair of non-nest site variables and compared them to nest site variables to investigate nest-site affinities. Non-nest sites were rejected if they did not contain at least one tree with structure suitable to support a nest. Sampling techniques followed those presented by James and Shugart (1970) and Dunk et al. (1997).

Home Range Delineation. Within the 10 640 ha core study area, we delineated Red-tailed Hawk home ranges by direct observation of unmarked male birds at seven breeding territories. Males and females of each breeding pair were distinguished by differences in molting patterns, plumage characteristics or size. We used a spotting scope and binoculars to observe movement patterns and continuously recorded time and activity data. Observa-

tion periods ranged from 2–5 hr, and were equally distributed between 0500 and 2000 H MST. Observations began in early April and continued through the fledging period or until the nesting attempt failed. We plotted the birds' position every 10 min and recorded locations on 1:24 000 topographic maps assisted by aerial photographs. The 10-min time interval was chosen to minimize dependency between successive locations (White and Garrott 1990). We used the ArcView extension ANIMAL MOVEMENT (Hooge and Eichenlaub 1997), to calculate 100% minimum convex polygon (MCP) home range estimates. We determined that home ranges defined by 100% MCPs best suited our needs because our primary goal was to define the outer-most boundary of use and describe general vegetation patterns therein.

We realized that several potential biases could have affected our home range delineations. First, by relying on direct observations of unmarked individual birds, territories could be: (1) underestimated in size as a result of birds sometimes being out of view (Village 1982, Baekken et al. 1987), (2) erroneously described due to failure to identify correctly the focal individual (Altmann 1974), or (3) to record accurately the location on a map of a bird that was greater than 300–400 lateral m from the observer. Our study area was conducive to direct observations, however, because it contained relatively open habitat and little topographic relief. We further mitigated potential biasing effects by careful selection of two or more observation points within each home range, and found that on average, birds were out of view during only 7.2% (SE = 1.39, range = 0–66 min) of each observation session Further, males in each territory were easily identifiable from a combination of individual morphological characteristics and because of rigorous territorial behavior,
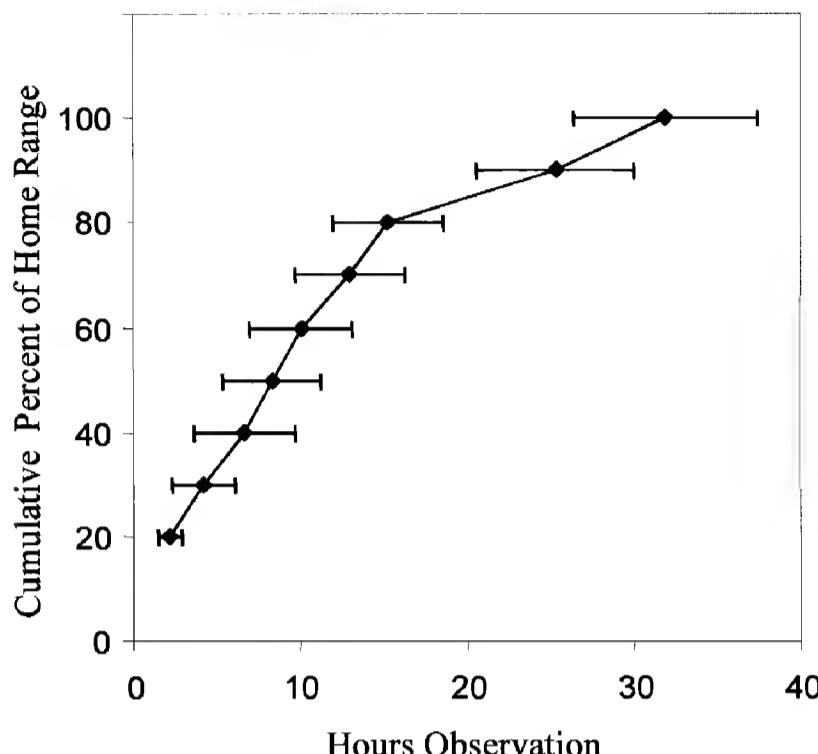
Figure 1. Mean cumulative percentage of home range size determined by hours of observation on seven Red-tailed Hawk territories in Grand Teton National Park, 1993–94. Horizontal bars indicate ± one SD of error.

thus, erroneous identification of individuals was probably rare. Territory size could also be underestimated by focusing observations on only one sex of the territorial pair. For example, during courtship, incubation, and early brood-rearing, female Red-tailed Hawk's movements were largely restricted to the nest site, while the male foraged for both sexes and defended their territory (Bent 1937, Newton 1979, Preston and Beane 1993). Delineation of home ranges is dependent upon obtaining a sample of locations large enough to accurately represent the area used (e.g., Bekoff and Mech 1984). Therefore, we addressed this by ensuring that for each territory observed, an asymptote in home range size plotted against observation time was obtained (Fig. 1).

Home Range Characteristics. Within each home range and the core study area, we used a ground-truthed digital vegetation cover-type database (Despain 1990) to categorize habitat into six classes: (1) coniferous forest, (2) deciduous forest, (3) mixture of deciduous and coniferous forest, (4) mixture of timber and shrub, (5) sage/shrub, and (6) grass/meadow. A digital elevation model was used to categorize aspect into eight classes and slope in four classes: 1–10%, 11–20%, 21–30%, and 31–40%.

Statistical Procedures. Univariate comparison of habitat variables at nest and non-nest sites were completed using two-tailed paired Student's *t*-tests. Comparisons between deciduous and coniferous nest tree characteristics were conducted using two-sample *t*-test. We used a stepwise discriminant-function analysis (DFA) with a forward-variable selection and a tolerance value of 0.15 to arrive at the best subset of habitat-related predictor variables most useful in separating nest plots from paired non-nest sites. We used a jackknife classification procedure and variables with canonical structure coefficients greater than 0.30 from the first stepwise discriminant procedure in a final discriminant analysis. To assess the effectiveness

of the DFA, we calculated Cohen's Kappa statistics for the classification matrix. This statistic indicates whether the model classified observations into their respective groups significantly better than by chance (Titus et al. 1984). We tested the randomness of the aspect of sites using Watson-Williams's (1956) multisampling testing of angles and Rayleigh's *z*-test (Zar 1984). Due to the small number of observed home ranges, we opted not to test hypotheses regarding these data, and present descriptive measurements of habitat use, slope, and aspect at the landscape scale. Descriptive statistics are presented as mean ± SE. Statistical analyses were conducted using Systat software (Wilkinson 1997).

RESULTS

Nest-tree Characteristics. We located 22, 29, and 23 occupied nests in 1992, 1993, and 1994, respectively. Of these 74 occupied nests, 12 were reoccupied twice during the three years of study, and two nests were occupied all three years. Habitat data from nests that were occupied in more than one year were included in our analyses only once. Nests were located in a variety of habitats, including riparian bottoms, timbered hillsides consisting of mixed conifer and deciduous trees, and in trees along irrigation ditches located in remnant agricultural areas. We found Red-tailed Hawk nests in six tree species; 22 (36.6%) were in coniferous and 38 (63.3%) were in deciduous trees (Table 2). One nest was in a snag. Two other tree species found in our study area, but not used by nesting Red-tailed Hawks were limber pine (*Pinus flexilis*) and subalpine fir (*Abies lasiocarpa*). Mean nest-tree height and mean nest height were higher in coniferous than deciduous trees ($t = 6.67$, $P < 0.001$, $\bar{x} = 26.98$ m vs. $\bar{x} = 18.15$ m, and $t_{58} = 6.05$, $P < 0.001$, $\bar{x} = 20.95$ m vs. $\bar{x} = 13.62$ m), respectively. We found no difference in nest-tree DBH or percent height of the nest in the tree between coniferous and deciduous nest trees. Douglas Fir (*Pseudotsuga menziesii*) nest trees were taller than the other five nest-tree species ($F_{1,54} = 13.2$, $P < 0.001$, $\bar{x} = 30.8$ m, SE $= 1.32$; Tukey HSD multiple comparisons). Mean nest diameter and depth were 81.3 cm (SE $= 0.43$, range $= 75–88$ cm) and 39.0 cm (SE $= 0.91$, range $= 29–61$ cm) respectively (*N* $= 50$ nests). There was no difference in nest size (diameter) among the three years ($F_{1,47} = 0.78$, $P = 0.46$).

Microhabitat Characteristics. Fifty of 60 (83.3%) nest trees were the tallest trees in the nest-site plot. Nest trees had the largest DBH in 48 of 60 (80%) plots. Mean aspect of slope at nest plots and non-nest plots differed from a uniform distribution

Table 2.   Mean characteristics of Red-tailed Hawk nests ($N = 60$) in northwest Wyoming, 1992–94 (standard errors in parentheses).

Tree Species	Number of Trees	Percent Total Nest Trees	Tree Diameter (cm) Mean	SE	Tree Height (m) Mean	SE	Nest Height (m) Mean	SE	Percent Tree Height[a] Mean	SE
Quaking aspen										
(*Populus tremuloides*)	22	37.5	33.4	1.8	17.6	0.84	12.7	0.67	72.2	(0.01)
Narrowleaf cottonwood										
(*Populus angustifolia*)	16	25.8	63.5	6.3	19.0	1.5	15.0	1.3	78.1	0.02
Douglas-fir										
(*Pseudotsuga menziesii*)	10	16.1	70.6	4.8	30.8	1.3	24.8	1.3	80.5	0.02
Lodgepole pine										
(*Pinus contorta*)	6	9.6	38.2	5.1	24.3	1.5	18.2	1.3	75.1	0.03
Blue spruce										
(*Picea pungens*)	4	6.4	57.6	4.9	23.3	1.9	17.7	1.6	76.0	0.02
Engelman spruce										
(*Picea engelmannii*)	2	3.2	46.5	3.5	23.3	0.4	16	1.0	69.0	5.1
All species	60		50.2	2.8	21.4	0.81	16.3	0.73	76.1	0.01

[a] Nest height divided by tree height × 100.

(Rayleigh's $z = 27.3$ and 43.3, respectively; $P < 0.001$), and the two sample means did not differ from each other ($F_{1,178} = 3.89$, $P > 0.25$; Watson-Williams test for two samples; Zar 1984). The mean slope aspect for the nest and non-nest plots was 347°. Nests were typically situated on 10–20% slopes. Univariate paired *t*-tests analyses indicated differences between nest plots and non-nest plots for five variables (Table 3). We found no difference between distances to forest edge at nest sites versus random sites from our univariate *t*-tests. However, discriminant function analysis included distance to edge along with canopy cover and basal area in a model that best explained the differences between nest and non-nest plots (Wilk's Lamdba = 0.82, $P < 0.0001$). Using the reduced model derived by

Table 3.   Mean microhabitat characteristics in 0.04 ha plots centered around Red-tailed Hawk nest sites ($N = 60$) and available sites ($N = 118$) in Grand Teton National Park, 1992–94.

Variables	Nest-Site Mean	SE	Non-Nest Site Mean	SE	Statistic *t*	*P*
Percent Canopy cover[a]	51.7	2.4	34.4	2.4	6.8	<0.01
Basal (m²/0.04 ha)	0.92	0.09	0.53	0.05	5.3	<0.01
Diam. breast ht[a]	29.8	1.9	24.9	1.0	2.9	0.01
Tree height[a]	14.1	0.67	12.5	0.47	2.7	0.01
Number of trees	13.3	1.2	11.1	0.91	2.1	0.03
Ground cover[a]	72.2	2.6	74.2	2.1	0.50	0.61
Shrub cover[a]	20.4	2.3	21.5	2.1	0.71	0.47
Foliage ht 0–0.3 m	68.8	3.6	70.5	3.1	0.58	0.56
Foliage ht 0.3–1 m	39.6	3.1	36.4	2.7	1.0	0.32
Foliage ht 1–2 m	26.9	2.9	24.9	2.4	0.67	0.50
Foliage ht 2–3 m	26.5	2.9	24.1	2.3	0.86	0.39
Distance to edge	21.7	3.2	22.9	3.4	0.24	0.81
Aspect[b]	NW (347°)	—	NW (347°)	—	—	—
Percentage slope	22.6	3.2	19.1	5.7	0.23	0.81

[a] Mean of plot means.
[b] Cardinal Direction, (mean azimuth, Watson-Williams 1956).

Table 4. Two-group discriminant function analysis of Red-tailed Hawk nest-site characteristics compared to non-nest (available) sites in northwest Wyoming for years 1992–94 combined.

| | GROUP MEANS (SE) | | STRUCTURE |
VARIABLE	NEST-PLOT	NON-NEST PLOT	COEFFICIENTS
Canopy cover	51.7 (2.4)	34.4 (2.4)	0.83
Basal area	0.92 (0.09)	0.53 (0.05)	0.41
Distance to forest edge	21.7 (3.2)	22.9 (3.4)	0.44
Sample size	60	118	
Wilk's lambda		0.82	
Approx. F-statistic		12.5[a]	
Cohen's kappa		4.9	
Percent correct classification	43/60 = 71.6	82/118 = 69.5	
Overall % correct classification		70.2	

[a] $P < 0.0001$

the stepwise DFA (Table 4), jackknife classification procedures successfully predicted 71% of nest sites and 69% of non-nest sites. The overall correct classification was 70.2%, which differed only slightly from a random classification rate (Titus et al. 1984).

Home Range Characteristics. On average it took 25 hr (range = 11.6–44.3, SE = 4.7, N = 7) of observation to delineate 90% of the home range, and 32 hr (range = 13.1–49.2, SE = 5.5, N = 7) for 100% delineation (Fig. 1). Total observation time by nest ranged from 24.5–73.5 hr ($\bar{x}$ = 47.4, SD = 17.1). Mean MCP home range size was 241 ha (SD = 119 ha, range = 181–480 ha; Table 5). This mean was similar to the mean of 225 ha (SD = 1.0 ha, range = 77–385 ha) obtained for eight nesting pairs of Red-tailed Hawks on the same study area in 1947 (Craighead and Craighead 1956). Among the seven home ranges, the percentage of non-forested cover ranged from 48–95% ($\bar{x}$ = 76%). Also, we observed considerable variation in the percentage cover of shrubland and grass meadow vegetation types (5–83% and 4–63%, respectively), while the total percentage cover of each were relatively equal (Table 5). The core study area was characterized by 76% open vegetation, primarily sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), grasslands, and remnant agriculture, and 24% forested vegetation that included both coniferous and deciduous trees (Table 5). Relative to the core study area, four of seven home ranges contained considerably more grass/meadow cover type, and five of seven contained considerably less sage/shrub cover type. Similarly, two of seven home ranges contained slopes greater

than 11% (range = 0–26%). The core area contained more area of south and southeast aspects than the combined home ranges.

DISCUSSION

We observed Red-tailed Hawks nesting only in trees. In another Wyoming study area, 40% (N = 10) of Red-tailed Hawks nested on cliffs (MacLaren et al. 1988). Most, (83%) of the nests in our study area were situated high in forest canopy, in the top one-fourth of the tree, and in the tallest tree in the immediate area. These findings corroborate other studies that suggest Red-tailed Hawks select nest-sites that afford unobstructed access and a high viewpoint of the surrounding area (e.g., Orians and Kuhlman 1956, Bednarz and Dinsmore 1982, Preston and Beane 1993, Stout et al. 1998). Distance to forest edge and slope may also be important factors. For example, Speiser and Bosakowski (1988) reported Red-tailed Hawk nests significantly closer to forest openings than random plots in both young and mature hardwood forests, reporting a mean distance to forest edge of 155 m. Conversely, Titus and Mosher (1981) detected no difference in distance to edge between Red-tailed Hawk nest plots and random plots in western Maryland, and they reported a mean distance of 235 m to the nearest forest edge. Like Titus and Mosher (1981), we detected no difference between distances to forest edge at nest sites versus random sites. However, on average, nests in our study area were within only 15 m of large patches of sagebrush, grasslands or remnant cultivated fields, suggesting an attraction of open areas.

Several studies have reported nest sites situated

Table 5. Minimum Convex Polygon (MCP) home range sizes (100%) and vegetation cover for seven breeding pairs of Red-tailed Hawks in northwestern Wyoming, 1992–93.

Nest Territory	Days Obs.	Hours Obs.	100% MCP (ha)	Vegetative Cover in Hectares (%)							
				Non-Forested[a]	Forested	Conif. Forest	Decid. Forest	Mixed Forest	Forest/ Shrub	Sage/ Shrub	Grass/ Meadow
Green 92	7	26.4	180.9	146	34.9	9.3	1.3	17	7.3	51.6	94.4
				(80.7)	(19.3)	(5.1)	(0.7)	(9.4)	(4.0)	(28.5)	(52.2)
Hunter 92	7	24.5	162.6	78.1	84.6	6.4	33.8	1.5	42.9	37.7	40.4
				(48)	(52)	(3.9)	(20.8)	(0.9)	(26.4)	(23.2)	(24.8)
Lobo 92	10	31.5	480.1	373.3	106.9	32.0	51.7	0	23.2	355.3	18
				(77.7)	(22.3)	(6.7)	(10.8)		(4.8)	(74)	(3.7)
Moulton 93	15	73.5	318.1	299.5	18.6	0	18.6	0	0	263.8	35.7
				(94.5)	(5.5)		(5.9)			(82.9)	(11.3)
Blacktail 93	10	41.6	145.0	99.8	45.1	34.4	1.3	3.4	6.0	7.9	91.9
				(68.9)	(31.1)	(23.7)	(0.9)	(2.3)	(4.1)	(5.5)	(63.4)
S. Green 93	12	57.2	203.8	177	26.7	8.4	0	14.5	3.8	40.6	136.4
				(86.9)	(13.1)	(4.1)		(7.1)	(1.9)	(19.9)	(67)
Wilson 93	14	60	196.7	154	42.6	15.4	9.6	10.7	6.9	47.6	106.4
				(78.3)	(21.7)	(7.8)	(4.9)	(5.4)	(3.5)	(24.2)	(54.1)
Mean	10.7	47.4	241	192.3	51.3	15.1	16.6	6.7	12.9	117.5	74.7
				(76.4)	(23.5)	(7.3)	(6.3)	(3.6)	(6.4)	(36.9)	(39.5)
SE	3.1	17.1	119.3	42.0	12.2	5.0	7.4	2.7	5.7	52.8	16.5
				(6.1)	(5.6)	(2.9)	(2.8)	(1.4)	(3.4)	(11.1)	(9.7)
Totals	75	322.1	—	1327.7	359.4	105.9	116.3	47.1	90.1	823.1	523.2
				(78.7)	(21.3)						
Study area	—	—	—	7750.8	2805.3	1203.1	664.6	211.9	725.7	4970	2651.6
				(72.8)	(26.4)	(11.3)	(6.2)	(2.0)	(6.8)	(46.7)	(26.9)

[a] Non-forested areas (ha) within the study area also included: barren ground = 25, burned = 15, water = 88, and urban = 86 ha

on sloped hillsides (Titus and Mosher 1981, Bednarz and Dinsmore 1982, Speiser and Bosakowski 1988). Titus and Mosher's (1981) data implied that Red-tailed Hawks select for nest sites on steep hillsides, and Speiser and Bosakowski (1988) suggested that Red-tailed Hawks may gain better soaring capability and an easier, downward departure flight from the nest on steeper hillsides relative to nests on flat terrain. Although we found no difference in slope between nest and non-nest sites, nests were typically situated on moderately-sloped ($\bar{x}$ = 22%) hillsides, which also facilitated nest access and views of the surrounding terrain. We also regularly observed Red-tailed Hawks actively foraging while perched at the nest and tending nestlings (i.e., searching and stooping from nests during prey capture attempts), suggesting that foraging efficiency may be important in nest site selection. We believe that, in addition to tree height, both proximity to edge and slope were important for Red-tailed Hawks in our study area for the reasons discussed above, but that our technique for locating random plots (within 200 m of nest sites) may have biased our comparisons for these variables. Indeed, it is likely that the site-specific combination of tree height, slope, and distance to edge, as well as nest-tree branch structure, determines nest access.

Nest and non-nest sites in our study area were found predominately on north aspects and similar slopes (Table 3), however, this similarity may be a function of the relatively close proximity of a non-nest plot (within 200 m) from a nest tree. Two ecological factors may be relevant here. First, in our study area's temperate and relatively arid environment, moisture regimes associated with slope effect (Knight 1994) favored more well-developed forested areas on north aspects, simply providing the stands with more abundant large trees that were selected by hawks. Second, nests on north aspects may provide some protection from our study area's prevailing southwest winds and associated rain and snow. Similarly, several other studies have noted the importance of aspect in reducing possible negative effects of prevailing weather on nestling rap-

tors (Newton 1979, Titus and Mosher 1981, Bednarz and Dinsmore 1982, Speiser and Bosakowski 1988, Preston and Beane 1993, Stout et al. 1998).

We observed large variation in the proportion of habitat types used among the seven home ranges. The absence of strong vegetation preferences, other than open grass/meadow cover type, at the landscape scale may indicate that: the number of home ranges sampled were inadequate, or upon arrival onto territories, these birds are first selecting habitat from the scale of the nest tree and the microhabitat site second. If the hawks are selecting habitat at a larger scale, it appears to be smaller than that of the entire home range. Bingham and Noon (1997) found "core areas" of ca. 200 ha to be used much greater than other areas within the home ranges of Northern Spotted Owls (*Strix occidentalis*). Perhaps Red-tailed Hawks also select habitat at some intermediate scale between area immediately surrounding the nest and the home range boundary. For Red-tailed Hawks, it appears that the availability of adequate nesting trees and their proximity to foraging areas are important characteristics that influence their selection of breeding areas. Selection of open habitat with trees or forested components is a consistent finding in other studies of Red-tailed Hawk habitat (see Preston and Beane 1993), although Bednarz and Dinsmore (1982) investigated Red-tailed Hawk habitat features within 3.14 km² "home ranges" in Iowa and found home ranges typically contained equal proportions of woodland, pasture and croplands. But consistent with other studies, Bednarz and Dinsmore argue that open areas, particularly pasture land, provided the key foraging habitats for nesting Red-tailed Hawks in Iowa.

The importance of specific nest-site and home range variable comparisons among multiple studies is diminished in the absence of similar comparisons of larger landscape patterns. Other components, including vegetative structure and physiognamy, food availability (Luttich et al. 1970, Marquiss and Newton 1981), and the presence of territorial conspecifics and other competitors (Rothfels and Lein 1983), each undoubtedly influence nest-site and home range selection. For future evaluations of Red-tailed Hawk habitat, it would seem prudent to focus more effort at spatial scales between: (1) the microhabitat scale and the home range, and their influence on Red-tailed Hawk populations, especially where human-caused landscape changes are likely to occur (Craighead and Mindell 1981), and

(2) landscape features surrounding the home range. Nevertheless, when considering this and other Red-tailed Hawk habitat studies, common patterns emerge that underscore the importance of nest access, and open areas associated with forest/non-forest ecotones.

ACKNOWLEDGMENTS

LITERATURE CITED

ALTMANN, J. 1974. Observational study of behavior: sampling methods. *Behavior* 49:227–265.

BAEKKEN, B.T., L.O. NYBO, AND G.A. SONERUD. 1987. Home-range size of Northern Hawk Owls: dependence on calculation method, number of tracking days, and number of plotted perchings. Pages 145–148 *in* R.W. Nero, R.J. Clark, R.J. Knapton, and R.H. Hamre [EDS.], Biology and conservation of northern forest owls. United States Forest Service General Technical Report RM-142.

BENT, A.C. 1937. Life histories of North American birds of prey, Part. 1. U.S. Nat. Mus. Bull. No. 167.

BEKOFF, M. AND L.D. MECH. 1984. Simulation analyses of space use: home range estimates, variability, and sample size. *Behav. Res. Meth. Instr. Comp.* 15:32–37.

BEDNARZ, J.C. AND J.J. DINSMORE. 1982. Nest-sites and habitat of Red-shouldered and Red-tailed Hawks in Iowa. *Wilson Bull.* 94:31–45.

BINGHAM, B.B. AND B.R. NOON. 1997. Mitigation of habitat "take": application to habitat conservation planning. *Conserv. Biol.* 11:127–139.

CRAIGHEAD, J.J. AND F.C. CRAIGHEAD. 1956. Hawks, Owls, and Wildlife. Stackpole Co., Harrisburg, PA and Wildlife Management Inst., Washington, DC U.S.A.

CRAIGHEAD, F.C. AND D.P. MINDELL. 1981. Nesting raptors in western Wyoming, 1947 and 1975. *J. Wildl. Manage* 45:865–872.

DESPAIN, D.C. 1990. Cover types of Grand Teton National Park. Electronic ArcInfo grid file. Grand Teton National Park, Moose, WY U.S.A.

DUNK, J.R., S.L. CAIN, M.E. REID, AND R.N. SMITH. 1994 A high breeding density of common ravens in northwestern Wyoming. *Northwest. Nat.* 75:70–73.

——, R.N. SMITH, AND S.L. CAIN. 1997. Nest-site selection and reproductive success in Common Ravens. *Auk* 114:116–120.

HOOGE, P.N. AND B. EICHENLAUB. 1997. Animal movement extension to Arcview, Ver. 1.1. Alaska Biological Science Center, U.S. Geological Survey, Anchorage, AK U.S.A.

JAMES, F.C. AND H.H. SHUGART. 1970. A quantitative method of habitat description. *Audubon Field Notes* 24:727–736.

JANES, S.W. 1984. Influences of territory composition and interspecific competition of Red-tailed Hawk reproductive success. *Ecology* 65:862–868.

KNIGHT, D.H. 1994. Mountains and plains: the ecology of Wyoming landscapes. Yale Univ. Press, New Haven, CT U.S.A.

LUTTICH, S., D.H. RUSCH, E.C. MESLOW, AND L.B. KEITH. 1970. Ecology of Red-tailed Hawk predation in Alberta. *Ecology* 51:190–203.

MACLAREN, P.A., S.H. ANDERSON, AND D.E. RUNDE. 1988. Food habits and nest characteristics of breeding raptors in southwestern Wyoming. *Great Basin Nat.* 48: 548–553.

MADER, W.J. 1978. A comparative nesting study of Red-tailed Hawks and Harris' Hawks in southern Arizona. *Auk* 95:327–337.

MARQUISS, M. AND I. NEWTON. 1981. A radio-tracking study of the ranging behavior and dispersion of European Sparrowhawks. *J. Anim. Ecol.* 51:111–133.

NEWTON, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, SD U.S.A.

NOON, B.R. 1981. Techniques for sampling avian habitats. *In* D.E. Capen [ED.], The use of multivariate statistics in studies of wildlife habitat. USDA, USFS, General Technical Report RM-87. Rocky Mountain Forest and Range Experimental Station, Fort Collins, CO U.S.A.

ORIANS, G. AND F. KUHLMAN. 1956. Red-tailed Hawk and horned owl populations in Wisconsin. *Condor* 58:371–385.

PALMER, R.S. 1988. Handbook of North American birds, Diurnal Raptors Part 2. Yale Univ. Press, New Haven, CT U.S.A.

POSTUPALSKY, S. 1974. Raptor reproductive success: some problems with methods, criteria, and terminology. Pages 21–31 *in* F.N. Hamerstrom, Jr., B.E. Harrell, and R.R. Olendorff [EDS.], Management of raptors. Raptor Research Report No. 2. Raptor Research Foundation, Inc., Vermillion, SD U.S.A.

PRESTON, C.R. 1980. Differential perch site selection by color morphs of the Red-tailed Hawk (*Buteo jamaicensis*). *Auk* 97:782–789.

———. 1990. Distribution of raptor foraging in relation to prey biomass and habitat structure. *Condor* 92:107–112.

——— AND R.D. BEANE. 1993. Red-tailed Hawk (*Buteo jamaicensis*). *In* A. Poole and F. Gill [EDS.], The birds of North America, No. 52. The Academy of Natural Sciences Philadelphia, PA and The American Ornithologists' Union, Washington, DC U.S.A.

ROTHFELS, M. AND M.R. LEIN. 1983. Territoriality in sympatric populations of Red-tailed and Swainson's hawks. *Can. J. Zool.* 61:60–64.

SMITH, R.S., S.L. CAIN, S.H. ANDERSON, J.R. DUNK, AND E.S WILLIAMS. 1998. Blackfly-induced mortality of nestling Red-tailed Hawks. *Auk* 115:368–375.

SPEISER, R. AND T. BOSAKOWSKI. 1988. Nest site preferences of Red-tailed Hawks in the highlands of southeastern New York and northern New Jersey. *J. Field Ornithol.* 59:361–368.

STEENHOF, K. AND M.N. KOCHERT. 1982. An evaluation of methods used to estimate raptor nesting success. *J. Wildl. Manage.* 46:885–893.

STOUT, W.E., R.K. ANDERSON, AND J.M. PAPP. 1998. Urban, suburban and rural Red-tailed Hawk nesting habitat and populations in southeast Wisconsin. *J. Raptor Res* 32:221–228.

TITUS, K. AND J.A. MOSHER. 1981. Nest-site habitat selected by woodland hawks in the central Appalachians. *Auk* 98:270–281.

———, ———, AND B.K. WILLIAMS. 1984. Chance-corrected classification for use in discriminant analysis: ecological applications. *Am. Midl. Nat.* 111:1–7.

VILLAGE, A. 1982. The home range and density of kestrels in relation to vole abundance. *J. Anim. Ecol.* 51:413–428.

WATSON, G.S. AND E.J. WILLIAMS. 1956. On the construction of significance tests on the circle and the sphere. *Biometrika* 38:330–336.

WHITE, G.C. AND R.A. GARROTT. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, CA U.S.A.

WILKINSON, L. 1997. SYSTAT 8.0: the system for statistics. SYSTAT, Inc., Evanston, IL U.S.A.

ZAR, J.H. 1984. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, NJ U.S.A.

NEST AND ROOST HABITAT CHARACTERISTICS OF THE GREY-FACED BUZZARD IN NORTHEASTERN CHINA

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ABSTRACT.—The habitat of the Grey-faced Buzzard (*Butastur indicus*) has diminished substantially because of forest management for timber production and farmland reclamation in recent years. An understanding of the characteristics of nest and roost sites of this bird is important for its conservation. We studied Grey-faced Buzzards during their breeding season in Zuojia Nature Reserve, Jilin Province, China, from March 1996–August 1998. This species selected both nesting and roosting sites in mixed-deciduous forests that contained Korean larch (*Larix olgens*) more frequently than available in the study area. Most nests were located in Korean larches and in Chinese pines (*Pinus tabulaeformis*, 70%), whereas nests in broadleaf trees were relatively infrequent (30%). Eight nests (75%) were located on the upper third of a slope, three nests (19%) were located on the middle third, and one nest (6%) on the lower third. Buzzards used 11 tree species for roosting; however, (58%) of all roosts were located in three tree species (Korean larch, Chinese pine, and River birch [*Betula nigra*]). Higher canopy closure and taller trees best separated roost sites from random plots with a discriminant analysis. Mean roost height was 9.6 ± 0.5 m. Roost trees averaged 11.2 ± 0.6 m in height with mean DBH (diameter at breast height) of 16.9 ± 0.3 cm. Buzzards selected nest and roost sites in forests characterized by tall (>12 m) conifers, hardwood understory, and high canopy closure (>70%).

KEY WORDS: *Butastur indicus; habitat use; Grey-faced Buzzard; nest site; nest tree; roost site.*

CARACTERÍSTICAS DEL HABITAT DE LOS DORMIDEROS Y DE ANIDACION DEL BUITRE DE CARA GRIS DEL NORESTE DE CHINA

RESUMEN.—El hábitat del buitre de cara gris (*Butastur indicus*) ha disminuido substancialmente en los últimos años, a causa del manejo del bosque para la producción de madera y la recuperación de tierras para agricultura. Una comprensión de las características de los sitios de nido y de los dormideros de esta ave, es importante para su conservación. Estudiamos el buitre de cara gris durante su temporada de cría en la Reserva Natural de Zuojia, Provincia de Jilin, China, desde marzo del 1996 hasta agosto del 1998. Esta especie escogió sitios de anidación y dormideros en los bosques deciduos mixtos que contenían una mayor frecuencia de *Larix olgens* en el área del estudio. La mayoría de los nidos se localizaron en *Larix olgens* y *Pinus tabulaeformis*, 70%, mientras que los nidos que estaban en árboles de hojas anchas fueron relativamente poco frecuentes (30%). Ocho nidos (75%) fueron localizados en el tercio superior de una pendiente, tres nidos (19%) fueron localizados en el tercio medio, y un nido (6%) en el tercio inferior. Los buitres utilizaron 11 especies de árboles como dormideros; sin embargo el 58% fueron localizados en tres especies de árboles *Larix olgens, Pinus tabulaeformis* y *Betula nigra.* La cobertura del dosel y los arboles mas altos fueron separados de los dormideros mediante la utilización del analisis discriminante. La media de la altura de los dormideros fue de 9.6 ± 0.5 m. Los árboles que sirvieron como dormideros tuvieron una altura promedio de 11.2 ± 0.6 m, con media DAP (diámetro a la altura del pecho) de 16.9 ± 0.3 cm. Los buitres escogieron nidos y dormideros en bosques carac-

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terizados por altas coníferas (>12 m), árboles del sub-dosel, de madera dura con copas cerradas y altas (>70% alto de dosel).

[Traducción de César Márquez]

The large number of published reports that describe habitat selection and habitat characteristics among birds attests to the enormous variation observed and to the biological importance of this topic. In addition to its importance, an understanding of the response by birds to environmental habitat change is necessary before conservation strategies can be developed and implemented (Schmutz 1989). A theoretical framework for habitat selection has been provided by Fretwell and Lucas (1970), and functional and theoretical aspects of habitat selection have been summarized by Cody (1985). Within these frameworks, nest and roost characteristics are very important factors related to avian habitat selection.

Among subtropical birds, raptors are one of the least-studied groups and relatively little is known about their nest and roost characteristics. Grey-faced Buzzard (*Butastur indicus*) is a summer migrant in northeast China (Cheng 1987, Anonymous 1988). It seems that most of the Grey-faced Buzzards that breed in northeastern China migrate to Okinawa, Taiwan, the Philippines, Indonesia, Malaysia or nearby regions to winter (Chang 1980, Cheng 1987, Ehimekensibu et al. 1989, Deng et al. 1997). This buzzard has been listed as a threatened species in National Second Class Protected Species in China Data Book of Endangered Animals (Zheng and Wang 1998). The habitats of this species have been substantially reduced because of forest management for timber production and farmland reclamation in recent years (Zheng and Wang 1998). An understanding of the characteristics of nest and roost sites of this bird is particularly important for its conservation. However, very little is known about nesting ecology of Grey-faced Buzzards either in China or in other areas. In this paper we describe the nest and roost characteristics of this raptor in northeastern China. Our null hypotheses were: (1) no difference exists between nesting sites and randomly-placed plots within the study area, (2) no difference exists between the immediate nest site and general habitat within nest stands, and (3) no difference exists between roosting sites and randomly-placed plots within the study area.

STUDY AREA

The study area, ca. 84 km² in size, was located in Zuojia Natural Protection Area and included the Tumengling Mountains and Zhujia Mountains ranging from the eastern ChangBai Mountains to the western plain (126°1′–127°2′N, 44°6′–45°5′E). Elevation at the site ranged from 200–500 masl. The climate is east monsoon, characterized by hot, dry summers and cold, snowy winters. The vegetation within the study area was quite diverse, although the existing forest is secondary. The most common trees present in the study area were Mongolian oak (*Quercus mongolica*), dahur birch (*Betula davurica*), Manchurian linden (*Tilia mandschurica*), Japanese elm (*Ulmus japonica*), Scotch pine (*Pinus sylvestris*), Korean larch (*Pinus koraiensis*) and Masson pine (*Pinus massoniana*) (Deng et al. 1997). In the study area, hawthorn raspberry (*Rubus crataegifolius*), dahurian rose (*Rosa dahurica*), Korean rose (*Rosa doreana*), willowleaf spiraea (*Spiraea salicifolia*), ural falsespiraea (*Sorbaria sorbifolia*), prickly rose (*Rosa acicularis*), amur barberry (*Berberis amurensis*), amur honeysuckle (*Lonicera maacki*), manchur honeysuckle (*Lonicera ruprechtiana*), and sakhalin honeysuckle (*Lonicera maximowiczii*) dominated the shrub layer. The study area consists of ca. 30% open habitat and 70% forest habitat.

METHODS

Survey Methods. We surveyed the study area at least four times each year, 20 March–20 August, 1996–98, using conventions suggested by Newton and Marquiss (1982) and Steenhof (1987) to describe occupancy and activities at nesting sites. We attempted to locate all buzzard nests within the study area. We used behavioral cues and systematic searches of potential nest substrates to locate nests. We determined the sex of buzzards by body size and plumage characteristics (Deng et al. 1997). We established six transects in the study area ($\bar{x}$ = 3 km, range = 2–5 km). Each transect was 50 m wide and parallel to the forest edge. Each transect was divided into 100 m segments from one end to the other. Sites were surveyed within a 4-hr period beginning 30 min after sunrise by walking along each side, with 5-min stops at each 100 m interval. We walked along one side and came back along another one. A nesting area was considered occupied if a territorial pair or evidence of a territorial pair (such as observations of an incubating bird, nest construction, or nest maintenance) was observed, otherwise the area was classified as unoccupied. We located roosts (the perch location where a bird spends the night) by observing buzzards at roost sites. Only roost sites where buzzards remained stationary upon initial detection were used in analyses. We recorded eagle nest and roost locations with GPS receivers and plotted these on geologic survey maps to the nearest 10 m using Universal Transverse Mercator (UTM) coordinates.

Most of our habitat-sampling protocol was adopted from Seamans and Gutiérrez (1995). We measured site characteristics in sample plots centered on buzzard nest

trees and roost trees and at random locations in forest habitat. Detailed vegetations were collected in 12 nest stands and 12 random plots. Nesting habitat data were collected at four sample points 25 m from each nest in each cardinal direction. Also, four sample points were located in each cardinal direction and at a random distance between 100 m and 1000 m from the nest tree to represent available habitat. This sampling was designed to address nest-site level habitat selection occurring within a hypothetical Grey-faced Buzzard home range. In each nest stand, four sample points were measured within both nesting and available habitat to increase the number of points available for use in the assessment of model stability (Mueller-Dombois and Ellenberg 1974). We categorized the forest type (conifer, if the proportion of conifers was >70%; mixed conifer/broadleaf, if the proportion of conifer and broadleaf was near equal; broadleaf forest, if the proportion of broadleaf was >70%) and slope position (lower, middle, upper third) at each site, and measured 12 habitat characteristics. At each plot center, we estimated slope aspect with a compass, slope angle (%) with a clinometer, and relative canopy closure (%) with a spherical densiometer. We measured tree DBH (diameter at breast height in cm) with calipers, and tree height with a clinometer. We used a varible radius-plot method (Mueller-Dombois and Ellenberg 1974) to estimate basal area (m^2/ha) of conifers and broad-leaf trees. In addition, we recorded nest and roost tree species, percent height (roost height/tree height) relative to the height of the tree, and distance from nest trees to roost trees. We used the variance of tree height and variance of tree diameters of all trees in each sample plot as an index of forest structural heterogeneity.

Data Analysis. We pooled data among years after finding no difference using a series of Kruskall Wallis tests (Zar 1984), with sequential Bonferroni adjustments (Rice 1990). We compared forest types and slope position of eagle sites and random sites using chi-square analysis. We estimated the mean slope aspect of eagle nests and roosts using circular statistics (Batschelet 1981), and compared aspect of eagle nests and roosts with random sites using a Watson-Williams test (Zar 1984). We assessed univariate normality of the variables using skewness, kurtosis, and probability plots. We assessed the equality of variance of variables between groups using an F-max test. We used logarithmic and square-root transformations to normalize variables and equalize variances for variables that deviated from normal distribution. For analyses, we only used those variables which approximated a normal distribution and had comparable variances between groups, either before or after transformation. We tested the null hypotheses of no difference in variable means between eagle nest and roost plots and random plots using multivariate analysis of variance (MANOVA, Stevens 1996). For the MANOVA, we used Wilk's Lambda to compare linear combinations of variables between used and random sites. If the MANOVA was significant, we tested individual variables using a series of t tests with sequential Bonferroni adjustments. We used discriminant analysis (DA, Stevens 1996) to model data, to estimate which characteristics contributed the most to differences be-

tween groups. We used cross validation (Capen et al. 1986) to evaluate the stability of the DA model.

We took detailed measurements of all nest trees (age, height, DBH, canopy and nest height) using the same techniques used for measuring trees in sample plots. We estimated nest tree age by extracting a core sample with an increment borer and counting the rings. We used circular statistics to estimate mean orientation of the nest relative to the tree trunk. We used a chi-square analysis to test for differences in tree species between nest and random tree distributions. We used paired-sample t tests (Zar 1984) to compare nest tree height and DBH to random trees within nest stands.

RESULTS

Roost-site Characteristics. Of 86 roost sites we measured, we used 58 (one each for 30 males and 28 females) as independent samples for analysis. The distribution of forest types at Grey-faced Buzzard roosts differed from random sites throughout the study area ($\chi^2 = 9.06$, df $= 2$, $P < 0.05$), with most roosts in the mixed conifer/river birch forest type. Position of roosts sites on the slope differed from a random distribution ($\chi^2 = 9.06$, df $= 2$, $P < 0.05$). Forty-seven roosts (81%) were located on the middle third, eight (14%) roosts were on the upper third, and three roosts were (5%) on the lower third of the slopes. Mean aspect at roost sites differed from aspect at random sites ($F = 8.94$, df $= 1$, 112, $P < 0.05$; mean aspect $= 6.8°$, mean vector length $= 0.60$, angular deviation $= 68.5°$). Buzzards used 11 tree species for roosting, however over half (58%) of all roosts were located in three tree species (Korean larch, Chinese pine, and river birch). Mean roost height was 9.6 ± 0.5 m in the roost tree. Roost trees averaged 11.2 ± 0.6 m tall in height with mean DBH of 16.9 ± 0.3 cm.

Roost plots differed from random plots (MANOVA; Wilk's Lambda $= 0.51$, $F = 16.8$, df $= 10$, 109, $P < 0.05$). The t-tests indicated most variables differed between roost and random plots (Table 1). Higher canopy closure and taller trees best separated roosts from random plots in the DA (Table 2). The pooled DA correctly classified 78.6% of the roost and random plots (Table 3).

Nest-site Characteristics. We found 12 Grey-faced Buzzard nests and used all nest sites as independent samples for analysis (Fig. 1). The distribution of forest types at nests differed from random sites ($\chi^2 = 15.62$, df $= 2$, $P < 0.05$), with most nests in the mixed-conifer/river birch forest type. Position of nest sites on the slope differed from an independent distribution ($\chi^2 = 11.26$, df $= 2$, $P < 0.05$). Eight nests (75%) were located on

Table 1.   Habitat characteristics at Grey-faced Buzzard roost sites ($N = 58$) and random plots ($N = 58$) in the Zuojia and Tumengling mountains, northeastern China, 1996–98.

VARIABLE	MEAN ± SD		t^b	P
	ROOST	RANDOM[a]		
Tree height (m)	13.8 ± 1.5	9.1 ± 1.2	5.63	<0.01
Tree DBH (cm)	28.7 ± 11.3	21.2 ± 8.6	2.84	0.01
Tree basal area (m²ha⁻¹)	10.6 ± 4.9	9.3 ± 5.8	0.98	0.46[c]
Canopy closure (%)	81.9 ± 18.5	62.4 ± 13.1	8.56	<0.01
Tree height variance	1.9 ± 1.6	0.8 ± 0.5	4.29	<0.01
Tree DBH variance	3.9 ± 1.6	2.1 ± 0.9	2.91	0.01
Distance from water (m)	348.6 ± 57.9	401.2 ± 345.5	0.42	0.61
Tree crown volume (m³)	12.2 ± 5.5	7.9 ± 3.8	3.21	<0.01
Slope angle (%)	22.5 ± 11.4	13.6 ± 6.8	8.27	<0.01

[a] Random sites were located throughout the study area by using GIS.
[b] Degrees of freedom = 98.
[c] No significant difference.

the upper third of the slope, three nests (19%) were located on the middle third, and one nest (6%) on the lower third. Mean slope aspect at nest sites was northerly (mean aspect = 295°, mean vector length = 0.37, angular deviation = 56.5°), and differ significantly from random sites ($F = 15.13$, df = 1, 22, $P < 0.05$).

Nest plots differed from random plots (MANOVA; Wilk's Lambda = 0.68, $F = 7.96$, df = 8, 23, $P < 0.05$). The t-tests indicated that four of the eight variables differed between nest and random plots (Table 3). Larger DBH, taller trees, greater canopy closure, and greater basal area of mature trees best separated nest sites from random sites in the DA (Table 3).

Nest-tree Characteristics. Grey-faced Buzzard nests were located in five tree species. Fifty percent ($N = 6$) of nests were located in Korean larches, 25% ($N = 3$) were in Chinese pines, and 8% each were in river birch, Mongolian oak, Manchurian linden (*Tilia mandschurica*), respectively. Mean aspect deviation of the nests in the trees was northwesterly (mean aspect = 342.5°, mean vector length = 0.51, angular deviation = 56.5°), but did not differ from a random distribution ($z = 1.2$, $P > 0.05$). The distribution of random tree species differed from nest tree species ($\chi^2 = 8.9$, df = 2, $P < 0.05$). Nest trees were larger, denser, and taller than trees randomly located within the nest stand (Table 4).

Table 2.   Mean habitat characteristics at Grey-faced Buzzard nest ($N = 12$) and random plots ($N = 12$) in the Zuojia and Tumengling mountains, northeastern China, 1996–98.

VARIABLE	MEAN ± SD		t^b	P
	NEST	RANDOM[a]		
Tree height (m)	15.1 ± 2.2	10.6 ± 1.7	8.24	<0.01
Tree DBH (cm)	31.9 ± 9.2	25.2 ± 6.7	3.13	0.01
Tree basal area (m²ha⁻¹)	17.6 ± 5.1	9.6 ± 3.7	4.94	<0.01
Canopy closure (%)	84.5 ± 15.6	62.7 ± 22.0	8.76	<0.01
Tree height variance	1.5 ± 1.1	1.3 ± 0.6	0.87	0.42[c]
Tree DBH variance	3.2 ± 1.8	3.1 ± 0.8	0.69	0.49[c]
Distance from water (m)	229.5 ± 112.6	314.2 ± 258.6	0.28	0.87[c]
Tree crown volume (m³)	13.8 ± 6.9	8.1 ± 3.8	3.47	<0.01
Slope angle (%)	25.5 ± 8.5	21.3 ± 7.1	1.22	0.06[c]

[a] Random sites located in each cardinal direction from nest at a random distance between 100 and 1000 m.
[b] Degrees of freedom = 94.
[c] No significant difference.

Table 3. Discriminant analysis results of habitat characteristics at Grey-faced Buzzard roost and nest plots in the Zuojia and Tumengling mountains, northeastern China, 1996–98.

Variable	Roost Plots (N = 58)			Nest Plots (N = 12)		
	Mean Rank	Mean Structure Coefficient[a]	Pooled Data Structure Coefficient[a]	Mean Rank	Mean Structure Coefficient[a]	Pooled Data Structure Coefficient[a]
Tree height (m)	1.9	0.57	0.64	2.5	0.54	0.62
Tree DBH (cm)	6.3	0.21	0.33	6.6	0.29	0.28
Tree BA (m²ha⁻¹)	8.7	0.16	0.13	9.2	0.11	0.09
Canopy closure (%)	1.2	0.76	0.81	1.0	0.80	0.83
Tree height variance	2.7	0.53	0.58	3.6	0.35	0.59
Tree DBH variance	4.9	0.29	0.45	5.7	0.39	0.36
Distance from water (m)	9.9	0.04	0.03	9.9	0.07	0.01
Tree crown volume (m³)	3.1	0.42	0.53	3.9	0.55	0.44
Slope angle (%)	1.3	0.68	0.77	1.8	0.68	0.72

[a] Structure coefficient is correlation between a single variable and discriminant function.

Discussion

Most Grey-faced Buzzard nest and roost sites were found on the upper third of north-facing slopes. This corresponded to the distribution of mature mixed conifer/river birch forests on the study area. In addition, most nest and roost sites had an understory of Mongolian oak, which con-

Figure 1. The study area and locations of the nest sites (solid squares indicate nest location) of the Grey-faced Buzzard in Zuojia Nature Reserve, northeastern China.

tributed to the forest structure. Raptors have shown some selection for slopes, but slope orientation patterns were not always consistent (Klopfer 1965, Delannoy and Cruz 1988, McIntyre and Adams 1999, Nijman et al. 2000). In selecting nest sites, Grey-faced Buzzards avoid slopes with southern aspects. We suggest that the birds are selecting exposures to insulate the nest against hot weather conditions during incubation and to place their nests close to hunting habitat. Data from accipiter studies (Shuster 1980, Moore and Henny 1983, Speiser and Bosakowski 1987) also show an obvious avoidance of southern slope aspects for nesting.

The majority of nests (75%) were built in conifers rather than in deciduous hardwood trees. Grey-faced Buzzards preferred to build their nests in dense canopy closure of Korean larches and Chinese pines (Table 4). Broad-leaf trees were rarely used as nest trees despite the preference for broad-leaf trees in nest stands. We propose that broad-leaf trees are partly avoided because they seldom have a larger triple and quadruple primary crotches. All nest trees were generally greater in DBH and height when compared to those random trees (Table 4). Large raptors require large tree-forks to place the nest in (Newton 1979, Mader 1982). Grey-faced Buzzard nests were always situated below or in the bottom quarter of the tree canopy, which had an open branch structure. Raptors nest in the lower quarter of the canopy with open branch structure probably to allow the buzzards access to the nest both above and within the canopy; this positioning may also hide the nest

Table 4. Characteristics of Grey-faced Buzzard nest (N = 12) and random trees (N = 12) in the Zuojia and Tumengling mountains, northeastern China, 1996–98.

VARIABLE	MEAN ± SD		t[b]	P-VALUE
	NEST TREES	RANDOM TREES[a]		
Age (yr)[c]	56.2 ± 5.1	54.8 ± 3.4	0.16	0.91
Tree height (m)	18.8 ± 3.1	14.3 ± 2.6	4.23	<0.01
Tree DBH (cm)	32.5 ± 9.7	24.9 ± 9.2	3.44	<0.01
Tree crown volume (m³)	3.6 ± 1.1	2.4 ± 0.7	3.16	<0.01
Nest height (m)	12.5 ± 3.4	—	—	—

[a] Random trees were located a random distance (10–100 m) in a random direction from the nest tree.
[b] t values from matched pair test, significant at α = 0.05.
[c] Estimated by extracting at core sample with an increment borer and counting the rings.

from potential predators (Selas 1996, Malan and Robinson 2001). Cerasoli and Penteriani (1996) suggested that tree-nesting raptors might select trees for their size and structural features, such as a tall and open canopy, that allow unobstructed access to nests. In this study, however, Grey-faced Buzzard seem to prefer dense to open canopy for nesting.

In our study, Grey-faced Buzzards selected nest and roost sites primarily in mixed conifer/river birch forests in the largest and tallest trees, with relatively high canopy closure. Forests composed of larger trees with high variation in tree heights may provide an accessible prey base for buzzards and provide protection from potential disturbance from human activities. This kind of vegetation structure allows more small animals to occur and also prevents humans from entering. In addition, Grey-faced Buzzards are heat intolerant and may require mature, multi-storied forests to thermoregulate effectively (Feng 1991, Deng et al. 1997). The middle partition of north-facing slopes, forested with multi-storied mixed conifer habitat, may provide suitable cooler microclimates for buzzards. However, habitats such as hardwood forests seem to lack the complete vertical structure of most typical nest and roost sites.

Trees frequently used for roosting were often those with dense foliage or high canopy closure. In contrast, available trees rarely or never used for roosting appeared to provide little cover. In addition to concealing birds from potential human disturbance, the dense cover of most roost sites probably provided a favorable microclimate. We found that individuals often used the same roost site on successive days, although our presence may have disturbed the buzzards. Although we climbed up

each nest tree to measure the characteristics of nestlings in every five days during nestling period, the buzzards did not change their roost sites. Belthoff and Ritchison (1990) suggested that Eastern Screech-Owls (*Otus asio*) did not use the same roost site on successive days, and suggested reuse of sites could attract potential predators. However, repeated use of roost sites by Grey-faced Buzzards is very common, probably because they have few predators in the study area (Deng et al. 1997). Also, suitable roosts with dense foliage may be extremely limited in the study area.

The forest tracts inhabited by buzzards were large in extent as exemplified by the comparatively long distances (>15 km) to human habitation (Deng et al. 1997). Nest sites were also more often found in dense forests, where little disturbance of any kind occurred and that may have had a greater density and diversity of prey species than edge areas (Kojima 1982, Ricketts and Ritchison 2000). However, we found most nest sites closer to logging roads (or discernable trails) than random sites: six nests (50%) were very close (<30 m) and four (33%) were within 60 m. In our study, forests roads often represented the break in deep contiguous forests. In dense contiguous forests, logging roads may aid the buzzards by providing open flyways. On several different occasions, we observed buzzards flying, perching, and plucking prey along logging roads in the study area. Speiser and Bosakowski (1987) found Northern Goshawks (*Accipiter gentilis*) often nested near logging roads in northern New Jersey and southern New York. Raptors often nest near logging roads or in an exposed position that allows easy access to and from the nest to deliver sticks and prey.

Moore and Henny (1984) pointed out the im-

portance of past experience (success or failure) in nest site selection by raptors, but at least for first-time nesters, the role of early experience and imprinting to the natal habitat may be of primary importance (Newton 1979). For a variety of nonpasserines, studies of marked individuals have shown that nesting sites are more likely to be reoccupied in years following successful nesting attempts and abandoned after nesting failures (e.g., Newton and Marquiss 1982, Marks 1986, Thorstrom and Quixchán 2000). We did not quantify foraging habitat of the buzzards in our study area. Available information indicated that Grey-faced Buzzards commonly forage in open areas (e.g., pastures, marshes, paddy fields) where they find most of their prey (Kojima 1982, Ehimekensibu et al. 1989). Their foods mainly include frogs, reptiles, rodents, and some birds (Cheng 1987, Ching et al. 1989, Severinghaus 1991). According to our observations, Grey-faced Buzzards often hunt from perches, typically at a top of dead tree; once detected the buzzards then dive down to capture prey. Because our study did not involve marked Grey-faced Buzzards among years, whether the same individual birds reoccupied nests is open to question. Future studies should examine Grey-faced Buzzard Eagles in more detail and should address the nature and extent of individual variation in habitat use. Additional factors such as prey, density, prey accessibility, and competition with other raptors need to be addressed in future studies of the nestling ecology of Grey-faced Buzzards.

ACKNOWLEDGMENTS

LITERATURE CITED

ANONYMOUS. 1988. A study of the northward migration of Grey-faced Buzzard Eagles passing PaKua Mountain in the spring. *Ann. Taipei Wild. Bird Soc.* 12:12–18.

BATSCHELET, E. 1981. Circular statistics in biology. Academic Press, San Francisco, CA U.S.A.

BELTHOFF, J.R. AND G. RITCHISON. 1990. Roosting behavior of postfledging Eastern Screech-Owls. *Auk* 107: 567–579.

CAPEN, D.E., J.W. FENWICK, D.B. INKLEY, AND A.C. BOYNTON. 1986. Multivariate models of songbird habitat in New England forests, Pages 171–176 in J. Verner, M.L Morrison, and C.J. Ralph [EDS.], Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Univ. of Wisconsin Press, Madison, WI U.S.A.

CERASOLI, M. AND V. PENTERIANI. 1996. Nest-site and aerial point selection by Common Buzzards (*Buteo buteo*) in Central Italy. *J. Raptor Res.* 30:130–135.

CHANG, W.F. 1980. Travellers who do not need visas, the Grey-faced Buzzard Eagle. *Environment* 1:58–64.

CHENG, TSO-HIN. 1987. A synopsis of the avifauna of China. Science Press, Beijing, China.

CHING, H.C., S.T. YU, AND C.H. CHIANG. 1989. A survey of Grey-faced Buzzard Eagle hunting in ManChou Area. KenTing National Park, Taipei, China.

CODY, M.L. 1985. Habitat selection in birds. Academic Press, New York, NY U.S.A.

DELANNOY, C.A. AND A. CRUZ. 1988. Breeding biology of the Puerto Rican Sharp-shinned Hawk (*Accipiter striatus venator*). *Auk* 105:649–662.

DENG, W.H., X. WANG, AND W. GAO. 1997. Breeding habitat selection of the Grey-faced Buzzard Eagle. *J. Northeast Normal Univ.* 9:57–61.

EHIMEKENSIBU, KOCHIKENSIBU, OITAKENSIBU, AND MIYAZAKIKENSIBU. 1989. The migration route of Grey-faced Buzzard Eagle *Butastur indicus* from Shikoku to Kyushu. *Strix* 6:125–131.

FENG, H.L., G.Q. XIANG, AND K.Q. HANG. 1991. Observation on breeding Grey-faced Buzzard Eagle. Chinese Avian Studies, No. 3., Chinese Science Press, Beijing, China.

FRETWELL, S.D. AND H.L. LUCAS. 1970. On territorial behavior and other factors influencing habitat distribution in birds. I. Theoretical development. *Acta Biotheor* 9:16–36.

KOJIMA, Y. 1982. Territory and territorial behavior of the Grey-faced Buzzard Eagle *Butastur indicus. Tori* 30: 117–147.

KLOPFER, P. 1965. Behavioral aspects of habitat selection. a preliminary report on foliage preferences of birds. *Wilson Bull.* 77:376–381.

MADER, W.J. 1982. Ecology and breeding habitats of the Savanna Hawk in the Llanos of Venezuela. *Condor* 84. 261–271.

MALAN, G. AND E.R. ROBINSON. 2001. Nest-site selection by Black Sparrowhawks *Accipiter melanoleucus*: implications for managing exotic pulpwood and sawlog forests in South Africa. *Environ. Manage.* 28:195–205.

MARKS, J.S. 1986. Nest-site characteristics and reproductive success of Long-eared Owls in southwestern Idaho. *Wilson Bull.* 98:547–560.

MCINTYRE, C.L. AND L.G. ADAMS. 1999. Reproductive characteristic of migratory Golden Eagles in Denali National Park, Alaska. *Condor* 101:115–123.

MOORE, K.R. AND C.J. HENNY. 1983. Nest site character-

istics of three coexisting Accipiter hawks in northeast Oregon. *Raptor Res.* 17:65–76.

——— AND J. HENNY. 1984. Age specific productivity and nest site characteristics of Cooper's Hawks. *Northwest Sci.* 58:290–299.

MUELLER-DOMBOIS, D. AND H. ELLENBERG. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York, NY U.S.A.

NEWTON, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, SD U.S.A.

——— AND M. MARQUISS. 1982. Fidelity to breeding area and mate in sparrowhawks *Accipiter nisus. J. Anim. Ecol.* 5:327–341.

NIJMAN, V., S. VAN BALEN, AND R. SÖZER. 2000. Breeding biology of Javan Hawk-Eagle *Spizaetus bartelsi* in west Java, Indonesia. *Emu* 100:125–132.

RICE, W.R. 1990. A consensus combined p-value test and the family-wide significance of component tests. *Biometrics* 46:303–308.

RICKETTS, M.S. AND G. RITCHISON. 2000. Nesting success of yellow-breasted Chats: effect of nest site and territory vegetation strucure. *Wilson Bull.* 112:510–516.

SCHMUTZ, J.K. 1989. Hawk occupancy of disturbed grasslands in relation to models of habitat selection. *Condor* 91:362–371.

SEAMANS, M.E. AND R.J. GUTIERREZ. 1995. Breeding habitat of the Mexican Spotted Owl in Tularosa Mountains, New Mexico. *Condor* 97:944–952.

SELAS, V. 1996. Selection and reuse of nest stands by sparrowhawk (*Accipiter nisus*) in relation to natural and manipulated variation in tree density. *J. Avian Biol.* 27:56–62.

SEVERINGHAUS, L.L. 1991. The status and conservation of Grey-faced Buzzard-Eagles and Brown Shrikes migrating through Taiwan. Pages 203–223 *in* T. Salathé, [ED.]. ICBP Tech. Publ. 12. Taiwan, China.

SHUSTER, W.C. 1980. Northern Goshawk nesting requirements in the Colorado Rockies. *West. Birds* 11:89–96

SPEISER, R. AND T. BOSAKOWSKI. 1987. Nest-site selection by Northern Goshawks in northern New Jersey and southeastern New York. *Condor* 89:387–394.

STEENHOF, K. 1987. Assessing raptor reproductive success and productivity. Pages 157–170 *in* B.A. Giron Pendleton, B.A. Millsap, K.W. Cline, and D.M. Bird [EDS.], Raptor management techniques manual. Scientific and Tech. Series No. 10, Natl. Wildl. Fed., Washington, DC U.S.A.

STEVENS, J. 1996. Applied multivariate statistics for the social sciences, 3rd Ed. Lawrence Erlbaum Publishers, Mahwah, NJ U.S.A.

THORSTROM, R. AND A. QUIXCHÁN. 2000. Breeding biology and nest site characteristics of the Bicolored Hawk in Guatemala. *Wilson Bull.* 112:195–202.

ZAR, J.H. 1984. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, NJ U.S.A.

ZHENG, G.M. AND Q.S. WANG. 1998. China red data book of endangered animals. Chinese Science Press, Beijing, China.

FOOD HABITS AND FORAGING ECOLOGY OF AMERICAN KESTRELS IN THE SEMIARID FORESTS OF CENTRAL ARGENTINA

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Abstract.—The annual diet of the American Kestrel (*Falco sparverius*) was studied by analyzing 705 pellets and prey remains collected in a semiarid forest area of central Argentina. The diet composition fluctuated seasonally but was composed primarily of invertebrates, followed by small mammals, birds, and reptiles. Based on biomass, vertebrate prey was the major component of the diet in winter and spring. We found significant numerical differences between prey consumed by adult and nestling kestrels. Percentages of small mammal prey were higher in the diet of adults than in the nestlings, but rodents consumed by nestlings were larger in size than consumed by adults. Nestlings also ate more birds and reptiles than adults. Based in biomass contribution of vertebrate and invertebrate prey to the diet during non-breeding and breeding seasons, American Kestrels in semiarid forest of Central Argentina were more carnivorous than insectivorous predators. Differences between adult and nestling diets emphasized the importance of collecting samples from perches and nests when kestrel food habits are being studied during the breeding season.

Key Words: *American Kestrel; Falco sparverius; food habits; breeding season; semiarid forest; Central Argentina.*

HABITOS DE ALIMENTACIÓN Y ECOLOGIA DE FORRAJEO DE CERNÍCALOS AMERICANOS EN LOS BOSQUES SEMIARIDOS DEL CENTRO DE ARGENTINA

Resumen.—Estudiamos la composición anual de la dieta del Cernícalo Americano (*Falco sparverius*) en un área de bosque semiárido del centro de Argentina a través del análisis de 705 egagrópilas y restos presas. La composición de la dieta fluctuó estacionalmente pero fue compuesta en primer orden por invertebrados, seguidos en importancia por mamíferos, aves y reptiles. En términos de biomasa, los vertebrados fueron predominantes en la dieta en invierno y primavera. Encontramos diferencias significativas entre las presas consumidas por los cernícalos adultos y sus pollos. Los porcentajes de ocurrencia de pequeños mamíferos fueron mayores en la dieta de los adultos, pero los roedores consumidos por los pollos fueron más grandes. Además los pollos consumieron un mayor número de aves y de reptiles que los adultos. Tomando como base el aporte en biomasa de vertebrados e invertebrados durante las estaciones reproductivas y no-reproductivas, el Cernícalo Americano se presenta como un predador carnívoro en lugar de insectívoro para los bosques semiáridos del Centro de Argentina. Las diferencias observadas entre las dietas de los adultos y los pollos demuestran la importancia de conducir muestreos tanto en perchas como en nidos cuando se estudia el hábito alimenticio de este cernícalo durante la estación reproductiva.

[Traducción de los autores]

The American Kestrel (*Falco sparverius*) is widely distributed in North, Central, and South America inhabiting many different habitats and landscapes (Brown and Amadon 1968). In Argentina, the kestrel occupies subtropical forests in the north through shrubland steppes in Patagonia (Narosky and Yzurieta 1989, De la Peña and Rumboll 1998). The ecology and behavior of kestrels have been studied extensively (e.g., Roest 1957, Balgooyen 1976, Koplin et al. 1980, Rudolph 1982, Smallwood 1987, Varland et al. 1993). The food habits of this species have been documented in various habitats, but most of these studies have been carried out in Central and North America (see Heintzelman 1964 for a review, Jenkins 1970, Balgooyen 1976, Cruz 1976, Collopy and Koplin 1983). In the southernmost extreme of its range, the diet of kestrels has

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been examined only in Chile (Greer and Bullock 1966, Yañez et al. 1980, Simonetti et al. 1982) and there is one anecdotal record on the stomach contents from northeast Argentina (Beltzer 1990). All of these studies have quantified the diets, but no attempt has been made to assess the diet based on prey biomass. In addition, research has focused on the diet either during the winter or the breeding season, and no systematic study of the annual variation diet within a particular habitat has been completed. Similarly, studies in diet of kestrels during the breeding season have employed several different approaches (Lamore 1963, Balgooyen 1976), but none include a comparative analysis between prey consumed by adults and nestlings.

Here, we report the food habits of the American Kestrel in the semiarid forest of central Argentina and analyze the numerical and biomass contributions of vertebrate and invertebrate prey to the diet. We examine seasonal variations in the diet and show the differences in prey consumed by adults and nestlings during the breeding season.

STUDY AREA

This study was conducted in Parque Luro Reserve (36°55'S, 64°16'W), located in La Pampa province of central Argentina. The reserve (7604 ha) consists mainly of xerophytic open forests of caldén (*Prosopis caldenia*) which represents the characteristic landscape of the Espinal biome in the semiarid pampas of Argentina (Cabrera 1976). Forest areas in the reserve differ structurally, in part because of soil features, but mostly because of the effects of human disturbance. *Stipa* spp. are the dominant herbaceous species, and *Condalia microphylla, Lycium chilense, L. gillesianum,* and *Schinus fasciculatus* are the common shrub species when a middle stratum is present. Fieldwork was conducted in the tourist area of the reserve (450 ha) where forest fragmentation has been greater due to the clearing of native vegetation for the development of tourist and recreation facilities. Broad, open areas of natural *Stipa* grassland are common in this part of the reserve. Habitats surrounding the reserve consist of agricultural areas planted with crops, and perennial and annual pastures. Historically, these semiarid forests have been characterized as having hot summers and cold winters with low humidity and low annual rainfall, typically concentrated in spring and summer. However, unusually excessive rains have occurred during the last 11 years and the mean annual precipitation has increased to 791 ± 336 mm ($N = 11$).

METHODS

We collected American Kestrel pellets monthly from March 2000 to February 2001. Pellets and prey remains were collected beneath kestrel perches throughout the year and from five nest boxes occupied by pairs of kestrels during the breeding season. Pellets from adult kestrels were collected in perches located in three of the five territories where nest boxes were occupied. Pellets and prey remains found in nest boxes were assumed to represent the diet of nestlings and collected during the post-hatching period until the time when young kestrels left. Only fresh and compact pellets were collected both from perches and nest boxes.

Pellets collected were hydrated and broken apart by hand and remains of prey items were separated for identification. Mammals and lizards were identified on the basis of skulls and dentaries using reference collections and keys (Pearson [1995] for mammals and Cei [1986] for lizards) to the species and subfamily levels, respectively. Arthropods were identified using mandibles, heads, elytra, and any other parts that allowed identification to the subfamily level. In order to estimate the minimum number of individual prey in each sample, skulls were counted for mammal prey; skulls, legs, and feet were used for birds; skulls and tails were used for lizards; and whole heads, feet, elytra and mandibles were used for insects. When only hairs, bones, feathers, or scales were found in a pellet, one individual prey was counted in the sample and classified as unidentified.

To compute prey biomass, we obtained the mean body mass of adult small mammal species from Tiranti (1992) and Tiranti (unpubl. data) provided data for the body mass of juvenile tuco tucos (*Ctenomys* spp.). The mean body mass of the bird species was obtained from Fiora (1933). Unidentified passerine body mass was calculated as the arithmetic mean of the known species that we recorded in the diet (Fiora 1933, Salvador 1988, 1990). Lizard and arthropod biomass were obtained from specimens collected in the study area in three pit-fall traps (Corn 1994). Mean weights were calculated from six lizards (*Teius* spp. and *Cnemidophorus* spp.), 56 orthopterans, seven mantids (Mantidae), 46 ants (Formicidae), 18 homopterans, 37 coleopterans, 21 spiders (Araneae) and 15 scorpions (Bothruridae). For unidentified mammals, reptiles, and birds, we assigned them the average mass of prey contained in each taxa for the same sample.

We used chi-square analysis (Zar 1996) to test differences in diet between seasons and between the diets of adults and nestling kestrels during the breeding season. For this analysis, prey taxa were grouped into four major classes (vertebrates, Orthopterans, Coleopterans, and others) and their frequencies were pooled by season (21 March–21 June = Autumn, 21 June–21 September = Winter, 21 September–21 December = Spring, and 21 December–21 March = Summer). Correlation analysis was used to examine the relationship among percentage of Coleopterans and Orthopterans in the diet. These percentages were subjected to an angular transformation prior to analysis (Zar 1996).

Levin's index of food niche breadth (Marti 1988) was calculated for each sample as follows: $B = 1/\Sigma_{i=1}^{n} p_i^2$, where p_i is the proportion of prey in different categories To compare diet breadth between samples with different numbers of prey categories, we calculated the standardized food niche breadth following Colwell and Futuyma (1971): $B_{sta} = (B_{obs} - B_{min})/(B_{max} - B_{min})$, where B_{min} is the minimum niche breadth possible ($N = 1$), $B_{obs} =$ number of prey types observed, and $B_{max} = N$. This index ranged from 0–1. In order to evaluate differences in size of prey consumed by adult and young American Kestrels,

we calculated the mean prey size by summing the products of the number of individual prey items and their mass and then dividing by the total number of prey in the sample. Our statistical test comparing this parameter was based on the assumption that prey sizes consumed were normally distributed.

Comparative studies have demonstrated that pellet analysis is subject to a number of biases for specific raptor species (e.g., Mersmann et al. 1992). Although no similar studies have been conducted to assess these biases in the analysis of the diet of the American Kestrel, our results must be considered potentially biased in representing some prey types in the diet.

RESULTS

During the study period, we collected 284 pellets and 421 prey remains. A total of 3127 prey items were identified from three vertebrate and six invertebrate classes. Arthropods comprised about 93% of the total prey items followed by rodents (6%), birds (1%), and reptiles (<1%). In terms of biomass, rodents accounted for 47% of the diet followed by insects (42%), birds (8%), and reptiles (3%).

Seasonal Diet Composition. We found significant differences in the diet of American Kestrels between seasons ($\chi^2 = 256$, df $= 9$, $P < 0.01$). Orthopterans, mainly grasshoppers, were the most common prey item in all the seasons, but their occurrence in the diet varied seasonally (Table 1). The percentage of Orthopterans in diet was negatively, but non-significantly, correlated with the percentage of Coleopterans ($r = -0.90$, $N = 4$, $P = 0.09$; Fig. 1), which were only important in winter and spring when the percentage of Orthopterans decreased in the diet. The greatest food niche breadth and mean prey size were recorded during the breeding season due to the frequent occurrence of mammals, birds, and reptiles in the diet. The biomass of vertebrate prey was higher than for invertebrates in winter (64.4%) and spring (68.6%; Fig. 2), but the biomass of Orthopteran prey was higher (70.9%) in summer than all other prey groups combined.

Diets of Adult and Nestling Kestrels. On a numerical basis, we found significant differences between the diets of nestling and adult kestrels during the breeding season ($\chi^2 = 85.2$, df $= 3$, $P < 0.01$) (Table 2). The standardized food niche breadth of nestling was greater than that of adults, but the mean prey size was approximately the same for both age groups (Table 2). Although similar percentages of invertebrates were found in both diets, nestlings consumed more birds and reptiles

than their parents, while adults ate comparatively more rodents than nestlings. In addition, a partitioned analysis of the standardized food niche breadth resulted in similar values for adults and nestlings for invertebrate prey (adult breadth $= 0.20$ vs. nestling breadth $= 0.21$), but a greater index for nestlings when we considered only vertebrate prey (adult breadth $= 0.22$ vs. nestling breadth $= 0.39$). Considering the mean size of vertebrate prey, prey consumed by nestlings were also larger than prey consumed by adults (36.1 g and 26.8 g, respectively).

DISCUSSION

We found American Kestrels in semiarid forests of central Argentina to be generalized predators of invertebrate and small vertebrate animals. Insects occurred in the diet throughout the year with decreasing percentages of one insect prey offset by the increased ingestion of another insect group, making the total percentage of arthropods almost constant over the seasons. Based on our observations of insects and small vertebrates in the study area, we suggest that these fluctuations in invertebrate prey consumed were due to seasonal changes in their availability rather than due to prey selection by the kestrels. From 2225 orthopterans and coleopterans collected seasonally throughout the study period, only 6% of them were recorded during winter while 47% of the total were collected in summer.

The kestrels preyed most heavily on large prey such as vertebrates, only in winter when the prey were breeding. As far as rodents, adults preyed most heavily on tuco tucos (juvenile body mass $=$ 80 g) which they delivered to their young, and on vesper mice (*Calomys* spp.; body mass $= 16$ g), which they ate themselves. Even though all of the tuco tucos consumed were juveniles, they were considerably heavier when compared to the kestrel's body mass and with the body masses of available alternative mammalian prey. Similar prey sizes have been reported by Lamore (1963) and Balgooyen (1976), both of whom analyzed the diets of kestrels during the breeding season. Selection of different-sized rodent prey during the breeding season may be due to the different energy requirements of adult and nestling kestrels. Balgooyen (1976) found that a brood of four nestling kestrels needed almost twice the prey mass required by their parents between hatching and post-fledging (3973 g for four nestlings vs. 2142 g for the pair of

Table 1. Seasonal composition of the diet of American Kestrels (*Falco sparverius*) in semiarid forest in Parque Luro Reserve, central Argentina. N = Number of Prey and $\%$ = Percent Frequency.

	MASS (g)	AUTUMN		WINTER		SPRING		SUMMER	
		N	$\%$	N	$\%$	N	$\%$	N	$\%$
Vertebrates									
Rodents (subtotal)		32	4.7	75	7.8	67	6.3	6	1.4
Calomys spp.	16	10	1.5	14	1.5	21	2.0	1	0.2
Oligoryzomys flavescens	22	2	0.3	8	0.8	4	0.4	—	—
Akodon molinae	38	—	—	6	0.6	1	0.1	—	—
Akodon azarae	22	3	0.4	5	0.5	6	0.6	—	—
Graomys griseoflavus	61	—	—	—	—	1	0.1	—	—
Reithrodon auritus	74	—	—	—	—	—	—	1	0.2
Eligmodontia typus	17	—	—	1	0.1	1	0.1	—	—
Ctenomys spp.	80	—	—	—	—	5	0.5	—	—
Rodents unidentified		17	2.5	41	4.3	28	2.6	4	1.0
Reptiles (subtotal)		1	0.1	—	—	11	1.0	—	—
Polychrotidae	32	—	—	—	—	1	0.1	—	—
Teidae	29	—	—	—	—	10	0.9	—	—
Reptiles unidentified		1	0.1	—	—	—	—	—	—
Birds (subtotal)		1	0.1	1	0.1	27	2.5	—	—
Passeriformes	28	—	—	1	0.1	23	2.2	—	—
Columbina picui	47	—	—	—	—	3	0.3	—	—
Bird unidentified		1	0.1	—	—	1	0.1	—	—
Invertebrates									
Orthoptera (subtotal)		516	75.8	438	45.5	617	57.8	338	81.1
Acrididae	2.5	491	72.1	374	38.9	342	32.1	303	72.7
Tettigoniidae	2	14	2.1	8	0.8	25	2.3	11	2.6
Gryllidae	1.2	11	1.6	56	5.8	250	23.4	24	5.8
Mantodea									
Mantidae	1.4	33	4.8	8	0.8	11	1.0	26	6.2
Hymenoptera									
Formicidae	0.1	55	8.1	301	31.3	157	14.7	10	2.4
Homoptera									
Cicadidae	1.3	2	0.3	—	—	70	6.6	8	1.9
Coleoptera (subtotal)		37	5.4	133	13.8	89	8.3	27	6.5
Scarabaeidae	1.1	26	3.8	44	4.6	64	6.0	19	4.6
Carabidae	1.3	11	1.6	89	9.3	24	2.2	6	1.4
Curculionidae	1	—	—	—	—	—	—	1	0.2
Cerambycidae	1	—	—	—	—	—	—	1	0.2
Tenebrionidae	1	—	—	—	—	1	0.1	—	—
Arachnids									
Scorpionida	8	4	0.6	6	0.6	5	0.5	2	0.5
Araneae	1	—	—	—	—	13	1.2	—	—
Total number of prey items		681		962		1067		417	
Food niche breadth		1.79		3.48		5.00		1.82	
Standardized food niche breadth		0.07		0.19		0.20		0.07	
Mean prey size (g)		3.47		3.71		4.43		2.74	
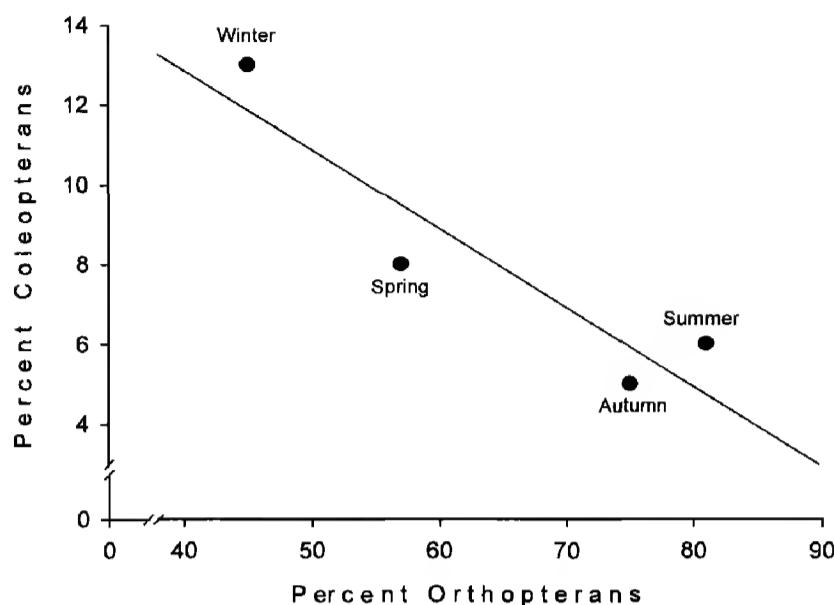
Figure 1. Relationship between percentage of Orthopterans versus percentage of Coleopterans in the diet of American Kestrels (each data point represents a season). The regression line is drawn only to emphasize the trend observed.

adults). High-energy demands of the nestlings might also explain why adults ate few birds, but fed a large number of birds to their nestlings. Birds such as House Sparrows (*Passer domesticus*) have been shown to have higher fat and gross energy content than voles (*Microtus pennsylvanicus*), and grasshoppers (*Melanoplus femur rubrum*) (Bird et al. 1982).

The kestrels we studied appeared to be rather

opportunistic in their feeding behavior when we consider the occurrence of tuco tucos in their diet. This fossorial, medium-sized rodent spends most of its life underground living in long and complex burrow systems feeding on roots and grasses (Redford and Eisenberg 1992). Kestrels probably prey on the young tuco tucos when they disperse from parental burrows.

Quantitative analyses of prey have shown the insectivorous nature of kestrels. However, an inverse relationship occurs when invertebrate and vertebrate biomasses in the diet are considered throughout the seasons. Jaksic et al. (1981) and Jaksic and Delibes (1987) have classified kestrels as carnivorous/insectivorous (in that order) and within the insect feeding guild, while Jaksic et al. (1993) classified kestrels as an omnivorous predator on the basis of dietary data collected during the breeding and nonbreeding (wintering) sampling periods. In all these studies, kestrels were trophically closer to Burrowing Owls (*Speotyto cunicularia*), which Silva et al. (1995) have suggested belong to a carnivorous instead of an insectivorous guild, based on the biomass dominance of vertebrate prey in the breeding and nonbreeding seasons (see Bellocq 1988). Vertebrate prey reflected the same prevalence in the kestrel diet in our study. When we combined our data into nonbreeding (autumm and winter) and breeding (spring
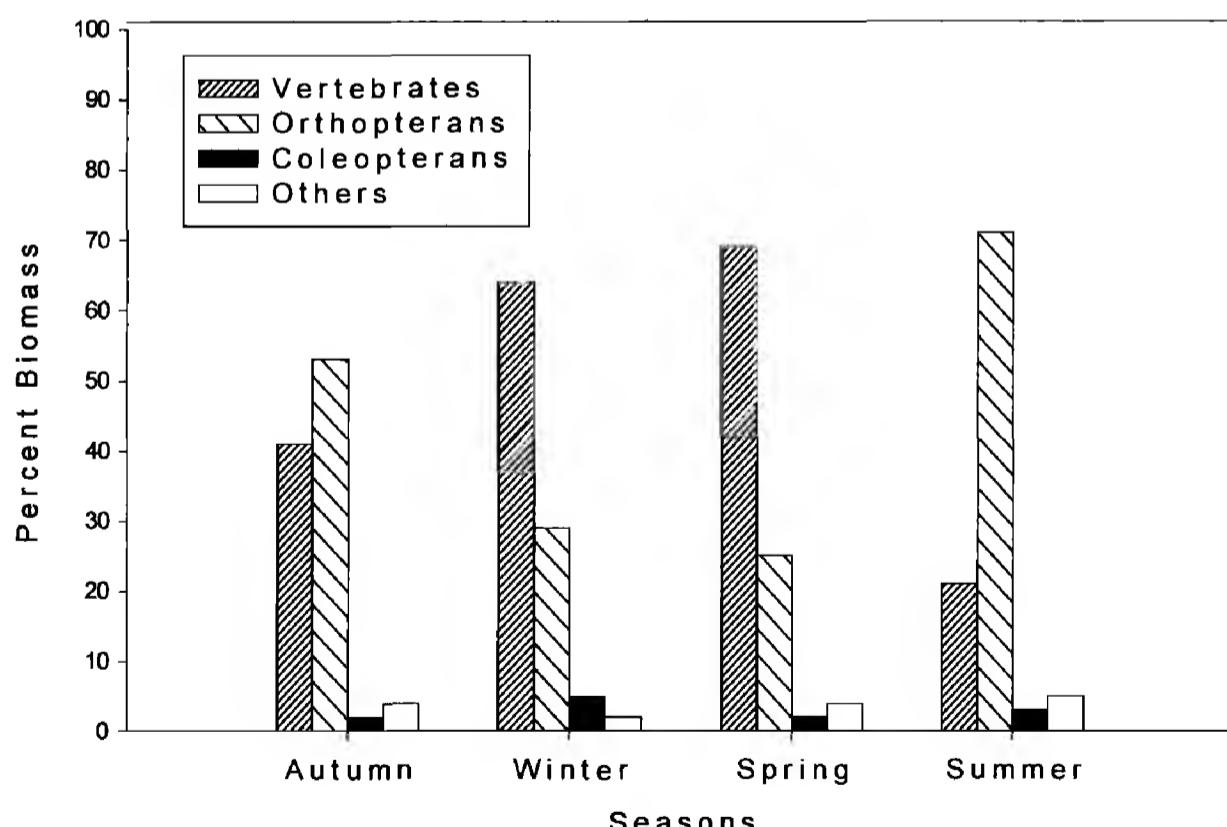
Figure 2. Percentage of biomass by season of the four major groups (Vertebrates, Orthopterans, Coleopterans, and other) of prey in the diet of American Kestrels in Parque Luro Reserve, Argentina.

Table 2. Composition of the diets of adult vs. nestling American Kestrels during breeding in Parque Luro Reserve Data from breeding season 2000 is pooled by age class (N = Number of Prey).

	ADULTS			NESTLINGS		
	N	PERCENT FREQUENCY	PERCENT BIOMASS	N	PERCENT FREQUENCY	PERCENT BIOMASS
Vertebrates						
Rodents (subtotal)	56	10.1	62.2	11	2.2	26.5
Calomys spp.	21	3.8	14.1	—	—	—
Oligoryzomys flavescens	4	0.7	3.7	—	—	—
Akodon molinae	1	0.2	1.6	—	—	—
Akodon azarae	6	1.1	5.5	—	—	—
Graomys griseoflavus	1	0.2	2.6	—	—	—
Eligmodontia typus	1	0.2	0.7	—	—	—
Ctenomys spp.	—	—	—	5	1.0	17.1
Unidentified rodents	22	4.0	34.1	6	1.2	9.5
Reptiles (subtotal)	1	0.2	1.2	10	2.0	12.5
Polychrotidae	—	—	—	1	0.2	1.4
Teidae	1	0.2	1.2	9	1.8	11.1
Birds (subtotal)	3	0.5	4.7	24	4.7	30.3
Passeriformes	1	0.2	1.2	22	4.3	26.3
Columbina picui	1	0.2	2.0	2	0.4	4.0
Unidentified birds	1	0.2	1.6	—	—	—
Invertebrates						
Orthoptera (subtotal)	254	45.7	25.8	363	71.0	25.0
Acrididae	234	42.1	24.5	108	21.1	11.5
Tettigoniidae	11	2.0	0.9	14	2.7	1.2
Gryllidae	9	1.6	0.5	241	47.2	12.3
Mantodea						
Mantidae	5	0.9	0.3	6	1.2	0.4
Hymenoptera						
Formicidae	153	27.5	0.6	4	0.8	—
Homoptera						
Cicadidae	1	0.2	0.1	69	13.5	3.8
Coleoptera (subtotal)	75	13.5	3.6	14	2.7	0.8
Scarabaeidae	61	11.0	2.8	3	0.6	0.1
Carabidae	13	2.3	0.7	11	2.2	0.6
Tenebrionidae	1	0.2	0.0	—	—	—
Arachnids						
Scorpionida	4	0.7	1.3	1	0.2	0.3
Araneae	4	0.7	0.2	9	1.8	0.4
Total number of prey items		556			511	
Food niche breadth		3.44			3.38	
Standardized food niche breadth		0.13			0.17	
Mean prey size (g)		4.30			4.59	

and summer) seasons, the percentage of vertebrate biomass was higher than invertebrates during the nonbreeding season (54%), but also during the breeding season (55%). Therefore, we agree with Jaksic et al. (1981) and Jaksic and Delibes (1987) and consider the kestrel to be a carnivorous/insectivorous predator.

Finally, demonstration of significant differences between the diets of adult and nestling kestrels indicated that food habit studies of this raptor should take into account age-related differences in the diet. If the diet during the breeding season is to be described, samples of pellets and prey remains should be collected both at the nest site and from perches used by the adult kestrels.

LITERATURE CITED

BALGOOYEN, T.G. 1976. Behavior and ecology of the American Kestrel (*Falco sparverius* L.) in the Sierra Nevada of California. Univ. Calif. Publ. Zool. 103.

BELLOCQ, M.I. 1988. Dieta de *Athene cunicularia* (Aves, Strigidae) y sus variaciones estacionales en ecosistemas agrarios de la Pampa, Argentina. *Physis Secc.* C 46: 17–22.

BELTZER, A.H. 1990. Biología alimentaria del halconcito común *Falco sparverius* en el valle aluvial del río Parana Medio, Argentina. *Hornero* 13:133–136.

BIRD, D.M., S.K. HO, AND D. PARÉ. 1982. Nutritive values of three common prey items of the American Kestrel. *Comp. Biochem. Physiol.* 73:513–515.

BROWN, L.H. AND D. AMADON. 1968. Eagles, hawks and falcons of the world. Vols. I and II. MacGraw-Hill, New York, NY U.S.A.

CABRERA, A.L. 1976. Regiones fitogeográficas argentinas. Enciclopedia Argentina de Agricultura y Jardinería. Editorial Acme, Buenos Aires, Argentina.

CEI, J.M. 1986. Reptiles del centro, centro-oeste y sur de la Argentina: Herpetofauna de las zonas áridas y semiáridas. Museo Regionale di Scienze Naturali, Monografie IV, Torino, Italy.

COLLOPY, M.W. AND J.R. KOPLIN. 1983. Diet, capture success, and mode of hunting by female American Kestrels in winter. *Condor* 85:369–371.

COLWELL, R.K. AND D.J. FUTUYMA. 1971. On the measurement of niche breadth and overlap. *Ecology* 52:267–276.

CORN, P.S. 1994. Straight-line drift fences and pitfall traps. Pages 109–117 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek and M.S. Foster [EDS.], Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians. Smithsonian Institution Press, Washington, DC U.S.A. and London, U.K.

CRUZ, A. 1976. Food and foraging ecology of the American Kestrel in Jamaica. *Condor* 78:409–412.

DE LA PEÑA, M.R. AND M. RUMBOLL. 1998. Birds of southern South America and Antarctica. Harper Collins, London, U.K.

FIORA, A. 1933. El peso de las aves. *Hornero* 5:174–188.

GREER, J.K. AND D.S. BULLOCK. 1966. Notes on stomach contents and weights of some Chilean birds of prey *Auk* 83:308–309.

HEINTZELMAN, D.S. 1964. Spring and summer sparrowhawk food habits. *Wilson Bull.* 76:323–330.

JAKSIC, F.M., H.W. GREENE, AND J.L. YAÑEZ. 1981. The guild structure of a community of predatory vertebrates in central Chile. *Oecologia* 49:21–28.

——— AND M. DELIBES. 1987. A comparative analysis of food-niche relationships and trophic guild structure in two assamblages of vertebrate predators differing in species richness: causes, correlations, and consequences. *Oecologia* 71:461–472.

———, P. FEINSINGER, AND J.E. JIMÉNEZ. 1993. A long-term study on the dynamics of guild structure among predatory vertebrates at a semiarid Neotropical site. *Oikos* 67:87–96.

JENKINS, R.E. 1970. Food habits of wintering sparrowhawks in Costa Rica. *Wilson Bull.* 82:97–98.

KOPLIN, J.R., M.W. COLLOPY, A.R. BAMMANN, AND H. LEVENSON. 1980. Energetics of two wintering raptors. *Auk* 97:795–806.

LAMORE, D.H. 1963. Prey of a sparrowhawk family when raising young. *Wilson Bull.* 75:461.

MARTI, C.D. 1988. A long-term study of food-niche dynamics in the Common Barn-Owl: comparations within and between populations. *Can. J. Zool.* 66:1803–1812.

MERSMANN, T.J., D.A. BUEHLER, J.D. FRASER, AND J.K.D. SEEGAR. 1992. Assessing bias in studies of Bald Eagle food habits. *J. Wildl. Manage.* 56:73–78.

NAROSKY, T. AND D. YZURIETA. 1989. Birds of Argentina and Uruguay, a field guide. Asociación Ornitológica del Plata, Buenos Aires, Argentina.

PEARSON, O.P. 1995. Annotated keys for identifying small mammals living or near Nahuel Huapi National Park or Lanín National Park, southern Argentina. *Mastozoología Neotrop.* 2:99–148.

REDFORD, K.H. AND J.F. EISENBERG. 1992. Mammals of the

neotropics. The southern cone. Vol. 2. Univ. Chicago Press, Chicago, IL U.S.A.

ROEST, A.I. 1957. Notes on the American Sparrowhawk. *Auk* 74:1–19.

RUDOLPH, S.G. 1982. Foraging strategies of American Kestrels during breeding. *Ecology* 63:1268–1276.

SALVADOR, S.A. 1988. Datos de peso de aves Argentinas. *Hornero* 13:78–83.

———. 1990. Datos de pesos de aves Argentinas 2. *Hornero* 13:169–171.

SILVA, S.I., I. LAZO, E. SILVA-ARANGUIZ, P. MESERVE, AND J.R. GUTIERREZ. 1995. Numerical and functional response of Burrowing Owls to long-term mammal fluctuations in Chile. *J. Raptor Res.* 29:250–255.

SIMONETTI, J.A., H. NUÑEZ, AND J.L. YAÑEZ. 1982. Falco sparverius L.: rapaz generalista en Chile Central. *Bol. Mus. Nac. Hist. Nat. Chile* 39:119–124.

SMALLWOOD, J.A. 1987. Sexual segregation by habitat in American Kestrels wintering in southcentral Florida. vegetative structure and responses to differential prey availability. *Condor* 89:842–849.

TIRANTI, S.I. 1992. Barn Owl prey in southern La Pampa, Argentina. *J. Raptor Res.* 26:89–92.

VARLAND, D.E., E.E. KLAAS, AND T.M. LOUGHIN. 1993. Use of habitat and perches, cause of mortality and time until dispersal in post-fledging American Kestrels *J. Field Ornithol.* 64:169–178.

YAÑEZ, J.L., H. NUÑEZ, R.P. SCHLATTER, AND F. JAKSIC 1980. Diet and weight of American Kestrels in central Chile. *Auk* 97:629–631.

ZAR, J.H. 1996. Biostatistical analysis, 3rd Ed. Prentice Hall, Princeton, NJ U.S.A.

Short Communications

Vertebrate Prey in the Diet of Flammulated Owls in Northern Utah

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Key Words: *Flammulated Owl*; Otus flammeolus; *bats*; *diet*; *Utah*; *vertebrate prey*.

Flammulated Owls (*Otus flammeolus*) are small, migratory owls which breed in montane forests of western North America (McCallum 1994). They are predominately insectivorous and prey mainly on lepidopterans and coleopterans (Goggans 1986, Oleyar 2000, Reynolds and Linkhart 1987). However, Holt et al. (1987) reported two cases of Flammulated Owls taking or pursuing vertebrate prey in Montana. The first was of an owl with a vole (*Microtus* sp.) in its talons, and the second was of an owl pursuing songbirds at a feeder. McCallum (1994) found these reports suspect, questioned the accuracy of owl identification, and provided several alternative explanations. In Colorado, Linkhart and Reynolds (1994) found a *Peromyscus* sp. carcass in the nest of a Flammulated Owl and also offered alternative explanations for the carcass other than it being killed by the owl. One alternative was that a different species of owl delivered the food in response to begging calls. Holt (1996) provided examples of vertebrates in the diet of these owls (including stomach contents and nest remains) dating back to 1891. McCallum (1996) was reluctant to assign more ecological flexibility to the species than warranted because it was receiving much attention by land management agencies as a sensitive species (Verner 1994) with a possible preference for older forests (Reynolds and Linkhart 1992). He stressed that no one had actually witnessed a Flammulated Owl kill vertebrates, which leaves open the possibility that these events were owls scavenging rather than killing vertebrates.

We found 13 occurrences of vertebrate prey at 10 different Flammulated Owl nests while studying two populations in northern Utah since 1992 (Marti 1997, Oleyar 2000). In all but one case, remains were in occupied Flammulated Owl nests with 10–18-d-old nestlings. Other small owl species occurring in the area were Northern Saw-whet Owls (*Aegolius acadicus*) and Northern Pygmy-Owls (*Glaucidium gnoma* = *californicum*, currently under review). Saw-whet Owls also used nest boxes, but they and Flammulated Owls never used the same nest box in a single year. Additionally, no other species of owl was observed at any occupied Flammulated Owl nest. We rarely found cached food, and this was only in nest boxes currently occupied by Saw-whet Owls.

The Snow Basin study site is located directly east of Ogden, Weber County, UT, U.S.A. in the Wasatch-Cache National Forest. The Mantua study site is located 32 km north of Snow Basin and just south of Mantua, Box Elder County, UT. Elevations ranged from 1920–1980 m, and both study areas were in forests dominated by quaking aspen (*Populus tremuloides*) and big-toothed maple (*Acer grandidentatum*), with a few clusters of mixed conifers· Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and subalpine fir (*Abies lasiocarpa*). We checked nest boxes in late April or early May prior to Flammulated Owl arrival on the study area or selection of nest sites. Nest boxes facilitated documenting for prey remains, and we checked each box regularly during the breeding season. Occupied nests were monitored 1–2 times weekly until young fledged.

On several occasions we found remains of vertebrate prey at occupied or recently-occupied active Flammulated Owl nests. In 1994, two immature *Peromyscus* carcasses were in a nest box at Snow Basin, where the young fledged approximately one week previously. In 1997, two pairs of bat (Vespertilionidae) wings were found at a Flammulated Owl nest at Mantua. We inspected the box

earlier in the season, and these remains were not present at that time. Moreover, we found no other skeletal parts in the nest, suggesting to us that the remains were not simply bats that had died in the box. This would represent the first record of Flammulated Owls taking bats as prey. During this same year, we also discovered a wing and a leg of songbirds (Passeriformes) in separate Snow Basin Flammulated Owl nests. In 1998, we found the leg of an unidentified songbird in a nest at Mantua. A *Peromyscus* sp. carcass and the wing of an unidentified songbird were found in Snow Basin nests in 1999. On 15 July 2000 while visiting a nest to weigh and band young, one of the young was swallowing a *Peromyscus* sp. Initially, the hind feet and tail were hanging out of the owl's mouth, but the owl swallowed the mouse in entirety during the visit. During an earlier visit to the same nest, the female and young were observed in the box with the headless carcass of a medium-sized juvenile songbird, possibly an immature Western Tanager (*Piranga ludoviciana*). In 2001, we found another bat carcass in a Snow Basin nest where nestling Flammulated Owls were present. The skin of the bat had recently been ruptured below the rib cage. In a subsequent visit to the nest after young had fledged, most of the carcass was gone and apparently had been eaten. Based upon morphology of the remains and known distribution of bats in the area, the carcass was likely one of three large-footed *Myotis* species: western long-eared bat (*Myotis evotis*), little brown bat (*M. lucifugus*), or long-legged bat (*M. volans*).

In addition to prey remains found in nests, a study of Flammulated Owl feeding rates using a video camera mounted inside the nest in 1998 documented a male Flammulated Owl (female was brooding in box at time) delivering a rodent, probably *Peromyscus* sp. to the nest. The tape shows the female moving the carcass around after delivery, but batteries running the recorder expired before it could be determined if she fed the mouse to her young or ate it herself. No carcass was found in subsequent nest visits, so it is likely she did one of the two. In all, 93.3 hr of videotaping over two breeding seasons (1997 and 1998) yielded 1875 prey deliveries, of which only this one (0.053%) consisted of vertebrate prey (Oleyar 2000).

Our findings suggest that Flammulated Owls on occasion take vertebrate prey. We understand McCallum's (1996) concerns that no observations exist of vertebrates actually being killed by Flammulated Owls. After all, one of the enduring characteristics of science is its demand for evidence. Considering the dearth of knowledge on Flammulated Owl ecology, and that the species was receiving attention as a sensitive species in several Forest Service regions (Verner 1994), McCallum's reluctance to attribute a broader ecological niche to the species is also reasonable. However, remains we found in nest boxes included a variety of vertebrate taxa (birds, bats, and rodents), suggesting that Flammulated Owls will take a variety of prey types. When viewed along with previous

reports of the species taking vertebrate prey (see Holt 1996), there is no question that Flammulated Owls do on occasion consume vertebrate prey. Whether these events represent scavenging or killing of prey remains undetermined. Because most of the time, (>99.99% in our Utah studies), this owl takes invertebrate prey, there is little doubt that it is highly adapted for an insectivorous lifestyle and its ecological role as a predator centers on its insectivorous feeding behavior.

RESUMEN.—Mientras estudiamos la ecología reproductiva de *Otus flammeolus* en el norte de Utah entre 1994–2001, se encontró la presencia de 13 vertebrados presa. Restos de aves, roedores y murciélagos fueron encontrados en nidos ocupados por el búho, adicionalmente se captó, con una cámara de video, la entrega de un mamífero pequeño en el nido. Los vertebrados han sido raramente reportados como presas de estos búhos, los cuales abarcaron 0.01% de la dieta del búho.

[Traducción de César Márquez]

LITERATURE CITED

GOGGANS, R. 1986. Habitat use by Flammulated Owls in northeastern Oregon. M.S. thesis, Oregon State Univ, Corvallis, OR U.S.A.

HOLT, D.W. 1996. On winter records and vertebrate prey in Flammulated Owls. *J. Raptor Res.* 30:46–48.

———, J.A. HOY, AND P.L. WRIGHT. 1987. Occurrence and first nest record of Flammulated Owls in Montana. *J. Raptor Res.* 21:120–121.

LINKHART, B.D. AND R.T. REYNOLDS. 1994. *Peromyscus* carcass in the nest of a Flammulated Owl. *J. Raptor Res* 28:43–44.

MARTI, C.D. 1997. Flammulated Owls breeding in deciduous forests. Pages 262–266 *in* J.R. Duncan, D.H Johnson, and T.H. Nicholls [EDS.], Biology and conservation of owls of the Northern Hemisphere: proceedings of the second international owl symposium. USDA Gen. Tech. Rep. NC-190, St. Paul, MN U.S.A.

McCALLUM, D.A. 1994. Flammulated Owl. *In* A. Poole and F. Gill [EDS.], The birds of North America, No. 93, Academy of Natural Sciences, Philadelphia, PA and American Ornithologists' Union, Washington, DC U.S.A.

———. 1996. Diurnal sight records of Flammulated Owls and possible vertebrate prey in winter: the case for caution. *J. Raptor Res.* 30:49–51.

OLEYAR, M.D. 2000. Flammulated Owl (*Otus flammeolus*) breeding ecology in aspen forests of northern Utah: including responses to ski area development. M.S. thesis, Boise State Univ., Boise, ID U.S.A.

REYNOLDS, R.T. AND B.D. LINKHART. 1987. The nesting

biology of Flammulated Owls in Colorado. Pages 239–248 in R.W. Nero, R.J. Clark, R.J. Knapton, and R.H. Hamre [EDS.], Biology and conservation of northern forest owls. USDA For. Serv. Gen. Tech. Rep. RM-142, Ft. Collins, CO U.S.A.

————. 1992. Flammulated Owls in ponderosa pine: evidence of preference for old growth. Old-growth forests in the Southwest and Rocky Mountain Regions: proceedings of a workshop. USDA For. Serv. Gen. Tech. Rep. RM-213, Ft. Collins, CO U.S.A.

VERNER, J. 1994. Current management situation: Flammulated Owls. Pages 10–13 in G.D. Hayward and J. Verner [EDS.], Flammulated, Boreal, and Great Gray Owls in the United States: a technical conservation assessment. USDA For. Serv. Gen. Tech. Rep. RM-253, Ft. Collins, CO U.S.A.

NESTING HABITAT OF COOPER'S HAWKS IN NORTHERN GREAT PLAINS WOODLANDS

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Cooper's Hawk (Accipiter cooperii) nesting habitat has been described quantitatively in the eastern (Titus and Mosher 1981, Bosakowski et al. 1992), midwestern (Wiggers and Kritz 1991, Garner 1999, Trexel et al. 1999), southwestern (Fischer 1986, Kennedy 1988, Boal and Mannan 1998), and western (Reynolds et al. 1982, Moore and Henny 1983, Asay 1987) regions of North America, but not for the northern Great Plains, where the hawk has been considered a species of special concern due mainly to its perceived scarcity (Nenneman et al. 2002). Woodland habitat within the northern Great Plains was scarce prior to European settlement in the early 1900s, limited primarily to gallery forests along major rivers (Coues 1897, Stewart 1975). Since then, tree coverage has increased. For example, woodland area in northwestern and north-central North Dakota more than doubled during 1938–91 (T. Grant and R. Murphy unpubl. data). Cooper's Hawk nesting habitat in the region may differ from that in other regions due to isolation of avail-able woodland habitats, lower tree species diversity, and differences in structural complexity of woodlands. Recent studies have shown Cooper's Hawks to be markedly plastic in their nesting habits (Boal and Mannan 1998, Bielefeldt et al. 1998, Trexel et al. 1999). However, species-habitat relationships inferred from data collected in one region may not adequately predict Cooper's Hawk use of woodland habitat in another region (Kennedy 1988, Trexel et al. 1999).

Our objectives were to: (1) describe quantitatively habitat characteristics of Cooper's Hawk nest-sites across the Souris River basin of North Dakota, (2) compare nest site habitat used to woodland habitat available, and (3) compare Cooper's Hawk nesting habitat in North Dakota to that in other regions.

STUDY AREA AND METHODS

Our study area was the Souris River basin in north-central North Dakota (48°40′N, 101°25′W; Ward, Renville, and McHenry counties; Fig. 1). The area is characterized by level to rolling plains found within the Drift Plain physiographic region (Bluemle 1991). Climate is subhumid continental, with mean monthly temperatures ranging from −15°C in January to 20°C in July. Mean annual precipitation is about 42 cm, most of which falls as rain between April and September (U.S. Fish Wildl. Serv. unpubl. data).

The Souris River flows along a 110-km "loop" from Canada south into north-central North Dakota, then back north again (Bluemle 1991; Fig. 1). In 1994–95, we

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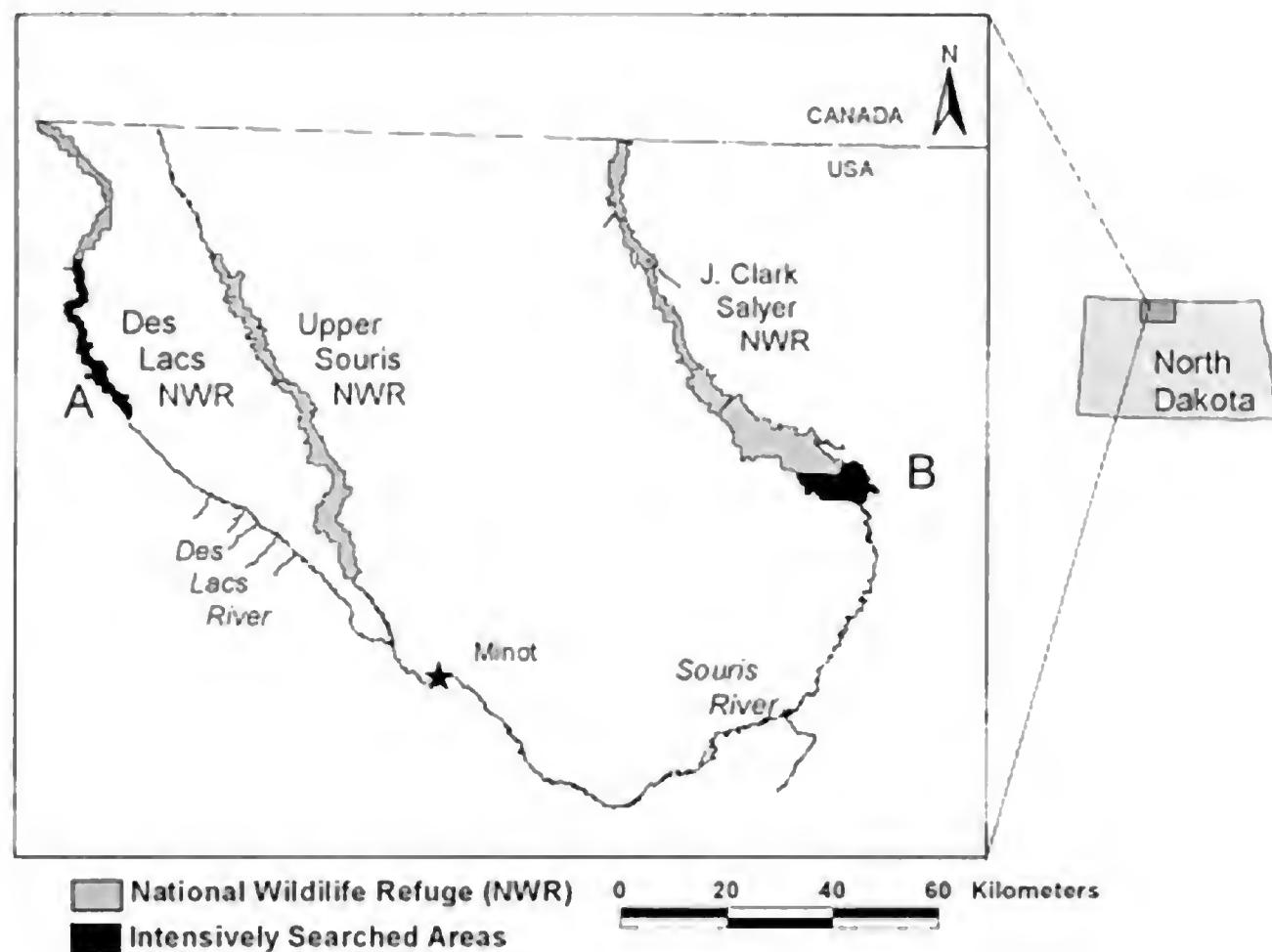
Figure 1. Cooper's Hawk study area in the Souris River basin of North Dakota, including two intensive search areas where nesting habitat use and availability were compared: (A) the southern one-half of Des Lacs National Wildlife Refuge (3951 ha) and (B) the far southern one-fifth of J. Clark Salyer National Wildlife Refuge (5263 ha).

located Cooper's Hawk nests in woodlands along the western one-half of this loop, the adjoining Des Lacs River, and intermittent tributaries ("coulees") of these rivers. Des Lacs and Upper Souris National Wildlife Refuges (NWR) were included, as well as privately-owned woodlands in Ward and southwestern McHenry counties. Des Lacs NWR has about 740 ha of woodland (10% of the refuge), mostly on north- and east-facing slopes of coulees. The Souris River has a narrow (<0.2 km wide) band of woodlands along its meandering bottoms, and wooded coulees in adjacent uplands.

In 1996, we located Cooper's Hawk nests along the eastern one-half of the Souris River loop, focusing our search for nests on the far southern part of J. Clark Salyer NWR (about 4000 ha of woodland, 17% of the refuge; Fig. 1). Here, the Souris River bisects an upland sandhills complex derived from the shores of glacial Lake Souris (Bluemle 1991). We also located nests in the Souris River floodplain woodlands adjacent to this sandhills complex.

Woodlands in our study area represented the naturally-occurring deciduous woodlands available in the northern Great Plains region: quaking aspen (*Populus tremuloides*)-bur oak (*Quercus macrocarpa*) woodland in the sandhills, green ash (*Fraxinus pennsylvanica*)-American elm (*Ulmus americana*) on north and east slopes of coulees, and green ash-American elm woodland in the river floodplain. The only other woodland habitat available within our study area was planted tree shelterbelts around farmsteads.

Woodlands were searched regardless of their perceived suitability for nesting (Trexel et al. 1999). We searched woodland habitat on foot during late April–June and found nests mainly by scanning individual trees (Nenneman et al. 2002). We completely searched all woodland habitat within two intensive search areas arbitrarily selected to determine Cooper's Hawk nesting density (Des Lacs NWR, 3951 ha and J. Clark Salyer NWR, 5263 ha; Nenneman et al. 2002). We restricted comparisons of nest-site habitat use and availability to these two areas. Additional nests were located by searching parts of other woodlands scattered throughout the study area. In Ward County, this included areas around nest sites originally identified during a 1986–87 breeding bird atlas (G. Berkey and R. Martin unpubl. data).

We quantified woodland habitat with techniques described by James and Shugart (1970) and Noon (1981). A 0.04-ha circular plot, centered on the nest tree, was the basis for nest habitat measurements (James and Shugart 1970, Trexel et al. 1999; Table 1). We measured habitat only once at each nest area (i.e., the area within 0.4 km of the first nest found [Rosenfield et al. 1995]), to avoid interdependency among sampling points (Bosakowski et al. 1992).

To assess nest habitat use by Cooper's Hawks, we compared habitat characteristics at nest sites with those at random woodland plots. We confined this analysis to nest sites located within our two intensive search areas. Woodlands at Des Lacs NWR were roughly linear (mostly <0.1 km wide), so we chose three to six plots centered at 200-m intervals from a random starting point (from 0–40 m from

Table 1.   Mean habitat characteristics of 48 Cooper's Hawk nest sites across north-central North Dakota, 1994–96.

CHARACTERISTIC	DESCRIPTION	$\bar{x}$ (SE)
Nest tree		
Nest height	Height (m) from ground to top of nest (meter tape)	9.2 (0.3)
Nest tree height	Height (m) of nest tree canopy (Abney level or rangefinder)	13.2 (0.4)
% nest height	(Nest height/tree height) × 100	69.7 (1.6)
DBH	Diameter of nest tree (cm) at breast height	24.7 (1.0)
Nest canopy cover	% canopy cover within a 1-m horizontal radius of the nest[a]	77.4 (2.9)
Nest site		
Canopy height	Mean height (m) of canopy of three trees in study plot	13.3 (0.4)
Stand DBH	Mean DBH (cm) of canopy trees in the study plot	16.0 (0.3)
Tree density	Number of canopy trees ≥7.5 cm DBH per ha.	1156.3 (64.0)
Basal area	Cross-sectional area (m²/ha) of canopy trees	25.9 (1.5)
Shrub density	Number of shrub stems (<7.5 cm DBH and >1.5 m tall)/ha	1364.1 (152.8)
% canopy cover	% of area over plot occluded by canopy tree foliage[b]	63.9 (2.2)
% ground cover	% of ground in plot covered by ground layer foliage[b]	72.1 (2.7)
Slope	Slope (degrees) of plot (Abney level)	3.0 (0.8)
Distance to water	Distance (m) to nearest permanent water source (pacing or measured from aerial photographs)	494.5 (72.0)
Distance to edge	Distance (m) to nearest opening in woodland canopy (pacing or measured from aerial photographs)	23.9 (2.8)
Stand age	Determined from core samples on the two largest trees[c]	63.5 (5.1)
Habitat (%) within 1 km of nest site		
Woodland	Percent of landscape covered by trees	24.6 (2.2)
Cropland	Percent of landscape covered by annually-tilled cropland	13.5 (2.5)
Grassland	Percent of landscape covered by native mixed-grass prairie (grazed or idle), planted grassland, or perennial forage crop	49.9 (2.4)
Wetland	Percent of landscape covered by riparian wet meadow or potholes	4.5 (1.3)
Open Water	Percent of landscape covered by rivers, lakes, or impoundments	5.7 (1.5)
Urban/other	Percent of landscape covered by cities, roads, etc.	2.0 (0.9)

[a] Ocular estimate.

[b] Forty ocular tube readings (James and Shugart 1970).

[c] Measured at 14 nest sites.

the woodland edge), on transects that bisected (linearly) the woodlands. We chose the nearest tree on a random compass bearing from the plot center to compare to nest trees. In sandhill woodlands at J. Clark Salyer NWR, we paced a random distance (up to 40 m) and direction in the field from random x-y coordinates identified on aerial photographs (1992, 1:7920), then selected the nearest tree along a random compass bearing as the center of the random plot (modified from Titus and Mosher [1981]). We determined percentage area of woodland, grassland, cropland, wetland, open water on rivers, and urban/other land use within 1 km (314 ha) of each nest and random plot using aerial photographs (1:21120, 1:7920) and an electronic planimeter or a dot grid.

We used standard statistical software (Hintze 1995) to conduct our data analyses. We grouped variables into subsets that characterized similar features, and conducted a multivariate analysis of variance (MANOVA) on each of these subsets. Variables characterizing the nest or cen-

ter tree (tree height and DBH) comprised one subset, and variables characterizing the nest or plot stand (canopy height, stand DBH, tree density, and percent canopy cover) comprised the second subset (Tables 2 and 3) Using these subsets and the remaining variables, we made seven (six at J. Clark Salyer NWR) simultaneous comparisons between nest sites and random plots for each intensive search area. To maintain an experiment-wise alpha of 0.10, we applied a Bonferroni correction (Sokal and Rohlf 1995); thus an alpha of 0.0143 was used for these simultaneous comparisons. When differences were detected, we compared individual variables with 2-tailed t-tests, or if data were non-normal, we used non-parametric rank tests (Mann-Whitney U-test) or unequal variance tests (Aspin-Welch [Hintze 1995]). Variables that did not logically fit into subsets (e.g., slope) were compared using 2-tailed t-tests. We used Chi-square goodness-of-fit tests to compare species composition of nest

Table 2. Mean (SE) values of habitat characteristics at Cooper's Hawk nest sites ($N = 11$) and random plots ($N = 32$) at Des Lacs National Wildlife Refuge, North Dakota, 1994–95.

HABITAT CHARACTERISTIC	NEST SITES	RANDOM PLOTS	P^a	P^b
Nest tree or center tree				
Height (m)	12.4 (0.8)	8.6 (0.6)		<0.001*
DBH (cm)	22.1 (1.6)	17.3 (1.7)	0.002	0.004
Nest site or random plot				
Canopy height	12.4 (0.6)	11.4 (0.6)		0.247
Stand DBH	15.0 (0.4)	15.4 (0.6)		0.821
Tree density (no./ha)	1054.5 (99.9)	755.5 (49.8)	0.090	0.017
% canopy cover	64.5 (4.1)	58.3 (3.1)		0.233
Shrub density (stems/ha)	1120.5 (224.9)	2010.2 (226.1)	0.009	
Slope (degrees)	7.0 (2.3)	12.6 (0.9)	0.043	
Distance to water (m)	422.9 (167.9)	302.4 (73.8)	0.358	
Distance to edge (m)	22.2 (4.7)	22.0 (3.1)	0.979	
Stand age (years)	59.9 (4.7)	72.6 (3.2)	0.041	

[a] P-value is for group MANOVA or t-test (rows that share a common P-value comprise a MANOVA group); experiment-wise alpha = 0 10.

[b] P-value is for Aspin-Welch Unequal-Variance t-test, except * denotes Mann-Whitney U-test.

trees used to that available based on center trees of 0.04-ha random plots.

RESULTS

We measured 48 Cooper's Hawk nests found during 1994–96. Cooper's Hawks tended to nest in woodland sites with dense canopies and high tree densities (Table 1). Canopy cover directly over individual nests was also high, with the exception of a nest in an aspen snag. Although shrubs were common at most nest sites (Table 1), shrub stem densities were highly variable, ranging from almost none in grazed woodlands to 4125 shrub stems/ha at one sandhill woodland site. Most nests (78%) were on slopes <5°, even though steeper wooded slopes (5–25°) were typical of coulee and some sandhill woodlands. Cooper's Hawks nested consistently close to woodland edge (Table 1). Distance to water, however, was more variable, ranging from 34–2000 m. Mean stand age (determined at three floodplain and 11 coulee nest sites) was 64 yr (Table 1), but nests occurred in stands as young as 35 yr.

Cooper's Hawks typically placed their nests within the lower part of the tree canopy, at slightly more than two-

Table 3. Mean (SE) values of habitat characteristics at Cooper's Hawk nest sites ($N = 18$) and random plots ($N = 40$) in sandhill woodlands at J. Clark Salyer National Wildlife Refuge, North Dakota, 1996.

HABITAT CHARACTERISTIC	NEST SITES	RANDOM PLOTS	P^a	P^b
Nest tree or center tree				
Height (m)	12.7 (0.4)	9.8 (0.4)		<0.001
DBH (cm)	23.8 (1.4)	17.5 (1.1)	<0.001	<0.001
Nest site or random plot				
Canopy height	12.7 (0.4)	10.7 (0.4)		<0.001
Stand DBH	15.9 (0.6)	15.5 (0.7)		0.387*
Tree density (no./ha)	1277.8 (112.0)	1042.5 (60.2)	0.012	0.076
% canopy cover	54.2 (3.0)	50.6 (2.2)		0.351
Shrub density (stems/ha)	2265.3 (230.0)	2510.3 (183.9)	0.410	
Slope (degrees)	1.0 (0.7)	5.1 (0.9)	<0.001*	
Distance to water (m)	677.7 (89.0)	665.3 (61.3)	0.909	
Distance to edge (m)	25.2 (6.3)	16.3 (2.2)	0.073	

[a] P-value is for group MANOVA or t-test (rows that share a common P-value comprise a MANOVA group); experiment-wise alpha = 0 10.

[b] P-value is for Aspin-Welch Unequal-Variance t-test, except * denotes Mann-Whitney U-test.

thirds of tree height (Table 1). Heights of nest trees and surrounding trees were similar (t_{94} = 0.23, P = 0.822), but nest tree DBH was larger than stand DBH (t_{94} = 9.78, P < 0.001). Nests were primarily in green ash (46%) or quaking aspen (31%); one (2%) was in an aspen snag, and remaining nests (21%) were in five other tree species.

Grassland, woodland, and cropland comprised most land cover within 1 km of Cooper's Hawk nests (Table 1). Wetlands, open water, and urban lands generally comprised a small portion of land cover around nests (means <6%), but were major components of land cover (31–44%) surrounding a few nests.

At Des Lacs NWR, nest trees were taller and larger than those available (Table 2). Nest sites had lower shrub density than random plots. Cooper's Hawks also appeared to select sites with less slope than that available. Two-thirds of the nests at Des Lacs NWR were on slopes ≤10°, compared to only one-third of the random plots. Nest tree species were used in proportion to their availability (χ^2_3 = 1.66, P > 0.50). Other variables were similar between nest sites and random plots at Des Lacs NWR.

At J. Clark Salyer NWR, nest trees again were taller and larger than expected based on random sampling (Table 3). Canopy height was greater, and slope was less at nest sites than at random plots. Tree species were used for nesting in proportion to their availability (χ^2_3 = 1.94, P > 0.50).

DISCUSSION

Cooper's Hawks breeding in North Dakota selected nest sites with less canopy cover and with shorter nest trees of lesser DBH compared to most other regions (Table 4). These differences may be due, in part, to structurally-inherent contrasts between woodlands in North Dakota when compared to other regions. Most woodlands in the northern Great Plains are relatively young (<100 yr), and the cool, subhumid continental climate (Stewart 1975:3) may slow tree growth. Although nest trees in this study were smaller than in other regions, Cooper's Hawks still placed their nests at about two-thirds of the nest tree height.

Cooper's Hawks nested in areas with a surprisingly small amount of woodland cover (as little as 1.0% within 1 km of nest), although most nested in areas with ≥10% woodland cover. Cooper's Hawks have also nested in an area in northwestern North Dakota where woodland may comprise only 2% of the landscape (Peterson and Murphy 1992).

We observed two parallel patterns of Cooper's Hawk nest-site use on our two intensive search areas; typically, sites with the greatest tree density and with little or no slope were used. Other authors (Reynolds et al. 1982, Bosakowski et al. 1992) have noted that most Cooper's Hawks nest in relatively flat terrain. Steeper slopes in our study area tend to have shorter trees due to drier and more poorly-developed soils. Trees on slopes also have relatively more exposed canopies than those on level ground.

Table 4. Reported Cooper's Hawk nest site characteristics (means) for North America.

STUDY AREA	NEST TREE CHARACTERISTICS					NEST SITE CHARACTERISTICS				SOURCE
	NEST HEIGHT (m)	TREE HEIGHT (m)	PERCENT NEST HEIGHT[a]	DBH (cm)	N	BASAL AREA (m²/ha)	PERCENT CANOPY COVER	DIST. TO EDGE (m)	N	
North Dakota	9.2	13.2	69.7	24.7	48	25.9	63.9	23.9	48	This study
North Dakota	6.2	9.5	65.4	20.0	13	—[b]	—	15	13	Murphy 1993
New York-New Jersey	16.7	25.0	67.3	44.0	21	30.9	88.9	120	21	Bosakowski et al. 1992
Maryland	15.4	—	67.5	44.5	6	24.3	76.0	129	6	Titus and Mosher 1981
Wisconsin	13.1	19.1	69.8	32.6	52	31.6	84.9	58	52	Trexel et al. 1999
NE Oregon	12.1	—	—	43.7	31	39.9	—	—	31	Moore and Henny 1983
NW Oregon	15.2	22.3	—	33.2	18	30.7	75.0	—	4	Reynolds et al. 1982
E Oregon	14.0	22.6	—	39.6	15	41.3	64.0	—	5	Reynolds et al. 1982
New Mexico	16.1	24.1	—	52.1	12	17.0	—	—	12	Kennedy 1988
Arizona	15.2	22.1	69.0	79.0	52	15.0	64.8	—	49	Boal and Mannan 1998
Utah	7.1	12.2	—	17.6	17	—	83.1	—	17	Fischer 1986
Arkansas	16.9	21.4	—	31.2	12	—	71.3	51.1	12	Garner 1999

[a] Percent nest height = (nest height/nest tree height) × 100
[b] Data unavailable

Distance to woodland edge was similar among nests and between nest sites and random plots on both intensive search areas, but was far less than reported elsewhere in North America (Table 4). Cooper's Hawk habitat in our study was relatively edge-dominated, with floodplain and coulee woodlands consisting of narrow, linear belts of timber and sandhill woodlands composed of timber interspersed within a grassland matrix. Despite these constraints of woodland configurations, North Dakota Cooper's Hawks placed nests near the center of woodlands, relatively "far" from edges. Distances from nests to water were extremely variable. Reynolds et al. (1982) and Boal and Mannan (1998) suggested that a nearby water source is important to nesting Cooper's Hawks in arid western and southwestern North America. However, our data and results from other studies (Titus and Mosher 1981, Bosakowski et al. 1992, Trexel et al. 1999) indicate that nesting near a permanent water source is not required in more temperate areas.

Our data, combined with those from other studies, indicate that nesting Cooper's Hawks exploit a wide array of woodland habitats across their range, including suburban and urban areas (Rosenfield et al. 1995, Boal and Mannan 1998), pine plantations (Wiggers and Kritz 1991, Rosenfield et al. 2000), and deciduous and coniferous forest (Titus and Mosher 1981, Reynolds et al. 1982, Bosakowski et al. 1992, Trexel et al. 1999). In our study area, Cooper's Hawks used natural woodlands, planted shelterbelts (R. Murphy unpubl. data), and even tall shrubs (Sondreal and Murphy 1998). In the northern Great Plains, such flexibility apparently has allowed Cooper's Hawks to exploit nesting habitat only recently available, and to become perhaps the most abundant breeding raptor in the region's sparsely distributed woodlands (Nenneman et al. 2002).

RESUMEN.—El gavilán de Cooper (*Accipiter cooperii*) ha sido poco estudiado como una especie que se reproduce en las Grandes Planicies, debido a esto, los responsables del manejo de los recursos en la región deben referirse a descripciones cuantitativas de otras partes de Norteamérica para identificar los hábitats probables de anidación. Durante 1994-96 se midieron las características del hábitat en 48 sitios de anidación del gavilán de Cooper, en una variedad de tipos de bosque en el centro-norte de Dakota del Norte. Los nidos se construyeron principalmente en arboles de *Fraxinus pennsylvanica*, 46% y de *Populus tremuloides*, 31%, en sitios de alta densidad de los mismos (0 = 1156 árboles/ah) y con una pendiente pequeña (0 = 3.0°). El gavilán de Cooper utilizó los sitios con menos cobertura de dosel (0 = 64%) y que estuvieran más cerca a los bordes de bosque (0 = 24 m) que lo previamente reportado. Comparado con los hábitats disponibles del bosque, el gavilán de Cooper anidó en bosques con menos pendiente y ubicó los nidos entre los árboles más grandes y altos. Los gavilanes de Cooper en periodo de anidación utilizaron los bosques con los atributos estructurales que fueran relativos a otras regiones.

Al igual que con los hallazgos recientes en otros hábitats, los datos apoyan la idea que el gavilán de Cooper explota una amplia serie de hábitats de bosque para su anidación.

[Traducción de César Márquez]

LITERATURE CITED

ASAY, C.E. 1987. Habitat and productivity of Cooper's Hawks nesting in California. *Calif. Fish Game* 73:80–87.

BIELEFELDT, J., R.N. ROSENFIELD, W.E. STOUT, AND S.M. VOS. 1998. The Cooper's Hawk in Wisconsin: a review of its breeding biology and status. *Passenger Pigeon* 60: 111–121.

BLUEMLE, J.P. 1991. The face of North Dakota. North Dakota Geol. Surv. Bismarck, ND U.S.A.

BOAL, C.W. AND R.W. MANNAN. 1998. Nest-site selection by Cooper's Hawks in an urban environment. *J. Wildl Manage.* 62:864–871.

BOSAKOWSKI, T., D.G. SMITH, AND R. SPEISER. 1992. Nest sites and habitat selected by Cooper's Hawks, *Accipiter cooperii*, in northern New Jersey and southeastern New York. *Can. Field-Nat.* 106:474–479.

COUES, E. (ED.). 1897. New light on the early history of the great Northwest: the manuscript journals of Alexander Henry and of David Thompson 1799–1814. Vol. 1. The Red River of the North. F.P. Harper, New York, NY U.S.A.

FISCHER, D.L. 1986. Daily activity patterns and habitat use of coexisting Accipiter hawks in Utah. Ph.D. dissertation, Brigham Young Univ., Provo, UT U.S.A.

GARNER, H.D. 1999. Distribution and habitat use of Sharp-shinned and Cooper's hawks in Arkansas. *J. Raptor Res.* 33:329–332.

HINTZE, J.L. 1995. Number Cruncher Statistical Systems (NCSS 6.0). Kaysville, UT U.S.A.

JAMES, F.C. AND H.H. SHUGART, JR. 1970. A quantitative method of habitat description. *Audubon Field Notes* 24· 727–735.

KENNEDY, P.L. 1988. Habitat characteristics of Cooper's

Hawks and Northern Goshawks nesting in New Mexico. Pages 218–227 *in* R.L. Glinski, B.G. Pendleton, M.B. Moss, M.N. LeFranc, Jr., B.A. Millsap, and S.W. Hoffman [EDS.], Proc. Southwest Raptor Manage. Symp. and Workshop, Instit. for Wildl. Res., Natl. Wildl. Fed., Natl. Wildl. Fed. Sci. and Tech. Ser. No. 11. Washington, DC U.S.A.

MOORE K.R. AND C.J. HENNY. 1983. Nest site characteristics of three coexisting Accipiter hawks in northeastern Oregon. *Raptor Res.* 17:65–76.

MURPHY, R.K. 1993. History, nesting biology, and predation ecology of raptors in the Missouri Coteau of northwestern North Dakota. Ph.D. dissertation, Montana State Univ., Bozeman, MT U.S.A.

NENNEMAN, M.P., R.K. MURPHY, AND T.A. GRANT. 2002. Cooper's Hawks, *Accipiter cooperii*, nest successfully at high densities in deciduous woodlands of the northern Great Plains. *Can. Field-Nat.* 116:573–577.

NOON, B.R. 1981. Techniques for sampling avian habitats. Pages 42–52 *in* D.E. Capen [ED.], The use of multivariate statistics in studies of wildlife habitat, U.S. For. Ser. Gen. Tech. Rep. RM-87. Rocky Mountain Forest and Range Exp. Station. Fort Collins, CO U.S.A.

PETERSON, D.J. AND R.K. MURPHY. 1992. Prey delivered to two Cooper's Hawk (*Accipiter cooperii*) nests in northern mixed grass prairie. *Can. Field-Nat.* 106:385–386.

REYNOLDS, R.T., E.C. MESLOW, AND H.M. WIGHT. 1982. Nesting habitat of coexisting *Accipiter* in Oregon. *J. Wildl. Manage.* 46:124–138.

ROSENFIELD, R.N., J. BIELEFELDT, J.L. AFFELDT, AND D.J. BECKMANN. 1995. Nesting density, nest area reoccupancy, and monitoring implications for Cooper's Hawks in Wisconsin. *J. Raptor Res.* 29:1–4.

——, ——, S.A. SONSTHAGEN, AND T.L. BOOMS. 2000. Comparable reproductive success at conifer plantation and non-plantation sites for Cooper's Hawks in Wisconsin. *Wilson Bull.* 112:417–421.

SOKAL, R.R. AND F.J. ROHLF. 1995. Biometry: the principles and practice of statistics in biological research W.H. Freeman and Co., New York, NY U.S.A.

SONDREAL, M.L. AND R.K. MURPHY. 1998. Low Cooper's Hawk, *Accipter cooperii*, nest in dense shrubs. *Can. Field-Nat.* 112:339–340.

STEWART, R.E. 1975. Breeding birds of North Dakota. Tri-College Center for Environmental Studies. Fargo, ND U.S.A.

TITUS, K. AND J.A. MOSHER. 1981. Nest-site habitat selected by woodland hawks in the central Appalachians. *Auk* 98:270–281.

TREXEL, D.R., R.N. ROSENFIELD, J. BIELEFELDT, AND E.A JACOBS. 1999. Comparative nest site habitats in Sharp-shinned and Cooper's hawks in Wisconsin. *Wilson Bull.* 111:7–14.

WIGGERS, E.P. AND K.J. KRITZ. 1991. Comparison of nesting habitat of coexisting Sharp-shinned and Cooper's hawks in Missouri. *Wilson Bull.* 103:568–577.

DYNAMICS AND TEMPORAL VARIATION IN AGE STRUCTURE AT A COMMUNAL ROOST OF EGYPTIAN VULTURES (*NEOPHRON PERCNOPTERUS*) IN NORTHEASTERN SPAIN

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The Egyptian Vulture (*Neophron percnopterus*) is a small vulture that occasionally gathers in communal roosts (Ceballos and Donázar 1990, Donázar et al. 1996). The existence of such roosts seems to be linked to abundant and regular food sources and also to the species' gregarious behavior under such conditions (Donázar 1993, Donázar et al. 1996). In small cathartid vultures, Rabenold (1983) has suggested that this behavior would be an adaptation in order to increase an individual's foraging efficiency on dispersed and unpredictable food supplies.

The Spanish population of Egyptian Vultures represents 80% of the total in the European Union, and has undergone a significant decline in recent years (Del Moral and Marti 2002). Communal roosts are thus important in terms of conservation, particularly bearing in mind that a large fraction of the preadult population concentrates in them (Donázar et al. 1996). The underlying causes leading to the formation and disappearance

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Table 1. Monthly variations in the number ($\bar{x} \pm$ SD) of Egyptian Vultures recorded at the roost between March and September 1998.

Month	Total Individuals (Range)	Adults (Range)	Immature (Range)
March ($N = 4$)	0	0	0
April ($N = 4$)	1 ± 1.7 (0–4)	0.75 ± 1.3 (0–3)	0.25 ± 0.4 (0–1)
May ($N = 6$)	8 ± 5.6 (0–16)	2 ± 1.5 (0–5)	6 ± 4.3 (0–11)
June ($N = 3$)	17.3 ± 2.4 (14–19)	11.7 ± 2.1 (9–14)	5.7 ± 0.9 (5–7)
July ($N = 5$)	5.4 ± 3.5 (0–10)	3 ± 2 (0–6)	2.4 ± 1.6 (0–4)
August ($N = 4$)	13.2 ± 5.5 (6–21)	7 ± 3.7 (2–11)	6.3 ± 2.4 (4–10)
September ($N = 2$)	2.5 ± 2.5 (0–5)	1 ± 1 (0–2)	1.5 ± 1.5 (0–3)

of such roosts, the possibility that local variations exist, and the movement of birds between roosts (Donázar et al. 1996), are reasons that justify the need for further information on the structure and dynamics of such aggregations in this species.

In this paper we describe the results obtained during a study on the dynamics and temporal variation in age structure at an Egyptian Vulture roost in Catalonia (north-eastern Spain) carried out for two consecutive seasons. We also discuss the factors leading to its formation and disappearance.

Study Area and Methods

The study was carried out in Catalonia, northeastern Spain. The breeding population of Egyptian Vulture in this region typically includes 34–40 pairs and its status has remained stable since the middle 1980s (D. García and A. Margalida unpubl. data). Even though the territories of breeding pairs have been monitored regularly, the first communal roost of this species in the area was not found until 1997 (Margalida 1997). Seven Egyptian Vulture pairs have their nests within a 10-km radius of the roost. Food availability is high and is a consequence of extensive livestock rearing of sheep, goats, and cattle (Margalida et al. 1997). The area where the roost is found has a mean annual rainfall of around 800 mm, with mean temperatures of 23°C (mean high) and 6°C (mean low). Dominant vegetation is of Mediterranean type with scattered forests consisting of white oak (*Quercus humilis*), holm oak (*Quercus ilex*), and Scotch pine (*Pinus sylvestris*).

In 1997, when the roost was formed, it was monitored weekly (Margalida 1997) and this was continued during 1998–99. Monitoring consisted of one visit per week for the period between March and September, with a total of 50 visits (28 in 1998 and 22 in 1999). June 1998, and April and August 1999 received only three visits each, which were spaced out every 10 d, so as to cover the whole month in a homogeneous way. In September, at the time of the post-breeding migration, observations were carried out during the first 10 days. In 2000, visits to the roost were carried out more or less sporadically until its disappearance was confirmed at the end of June.

Visits usually started in the early evening (1800 H, solar time), as birds began to arrive and settle in, and were

carried out until dusk (1900–2000 H), when birds stopped flying in the proximity of the roost. The number and age of the birds present was recorded in every visit. Age was established according to plumage following Ceballos and Donázar (1990), Tella (1991), and Donázar et al. (1996). Only two age categories were identified, because no young-of-the-year were found. These were: adults (individuals showing complete adult plumage, ≥4-yr birds) and immature (individuals showing some imperfection or with dark transitional plumage, 2-yr and 3-yr birds; Donázar 1993). Observations were carried out using 20–60× telescopes at a distance of over 500 m in order to minimize disturbance to the birds.

Results

In the study area, arrival of the first breeding individuals took place on 5 March 1998 and on 26 February 1999. In 2000, the first individual was observed on 3 March. In 1998, the first birds (three adults and one immature) started using the roost on 28 April (previous observation with no birds seen was on 19 April), and in 1999 (11 adults plus one immature) on 26 April (during observations on 19 April no birds were seen). The last birds were seen at the roost on 1 September (two adults and three immature) in 1998 and on 11 August in 1999 (one adult and one immature).

Location of the sleeping vultures changed between the years. While in 1997 they chose to perch on Scotch pines, a birch (*Betula pendula*), and a white oak (Margalida 1997), in 1998 and 1999 they chose a small forest of oak and, later, an isolated black poplar (*Populus nigra*). The latter was used in all the observations between May and September. In 2000, all the observations were made on the same poplar that had been used in 1999. Distance between the roost and the nearest predictable food source (a rubbish dump where carcasses were available regularly) was of some 2 km.

Altogether, no differences were noticed in the number of birds using the roost in the two study years. In 1998, the maximum number of birds sleeping simultaneously at the roost was 21 on 7 August (Table 1). In 1999, the maximum number of birds was also 21, on 5 June (Table 2). However, both in 1998 and in 1999, the mean largest

Table 2. Monthly variations in the number ($\bar{x} \pm$ SD) of Egyptian Vultures recorded at the roost between March and September 1999.

MONTH	TOTAL INDIVIDUALS (RANGE)	ADULTS (RANGE)	IMMATURE (RANGE)
March ($N = 2$)	0	0	0
April ($N = 3$)	9.3 ± 6.8 (0–16)	5.5 ± 6.0 (0–11)	0.5 ± 0.8 (0–5)
May ($N = 5$)	7.4 ± 7.3 (0–21)	4.2 ± 3.7 (0–11)	3.2 ± 3.6 (0–10)
June ($N = 4$)	17.3 ± 2.6 (14–21)	11.3 ± 1.1 (10–13)	6 ± 3 (3–11)
July ($N = 4$)	11.5 ± 5.7 (2–17)	4.8 ± 2.3 (1–7)	6.8 ± 3.5 (1–10)
August ($N = 3$)	0.7 ± 0.9 (0–2)	0.3 ± 0.5 (0–1)	0.3 ± 0.5 (0–1)
September ($N = 1$)	0	0	0

number of birds using the roost occurred in June, with 17.3 ± 2.4 birds ($N = 3$) and 17.3 ± 2.6 birds ($N = 4$), respectively (Tables 1 and 2). In terms of age classes, the largest number of adults were seen in June of both years. In contrast, birds in non-breeding plumage mostly concentrated in roosts in August in 1998 and in July in 1999 (Tables 1 and 2). With respect to birds of breeding age, differences between the years were found in May, with higher numbers in 1999, and in August, with less birds in 1999 (Tables 1 and 2). Differences in the number of non-breeding individuals were found in August, with fewer birds in 1999 (Tables 1 and 2).

Ninety-five (50.3%) of the 189 birds seen in 1998 ($N = 28$ visits) were adult and 94 (49.7%) were immature (Table 1). In 1999, 108 (59.3%) of the 182 birds seen ($N = 22$ visits) were adult and 74 (40.7%) were immature (Table 2). No significant differences were found between the years with respect to the number of adult birds present vs. immature ($\chi^2_1 = 2.73$, $P = 0.099$). Monthly variation (using only the highest single count made in each month) in both years neither was statistically significant (1998: $\chi^2_5 = 5.93$, $P = 0.31$; 1999: $\chi^2_4 = 2.56$, $P = 0.63$).

In both 1998 and 1999 there was a very similar pattern in the percentages of adults and immatures present at the roost (Fig. 1) and significant differences were only

Figure 1. Monthly variation in the proportion of birds of breeding age (white bars) vs. birds of non-breeding age (black bars) during the period April–September of 1998 and 1999.

found in May, when the reverse was found (25% adults vs. 75% immature in 1998 and 56.7% adult vs. 43.4% immature in 1999; $\chi^2_1 = 7.58$, $P < 0.001$).

In 2000 there were no systematic observations, but the presence of birds in the area of the roost was positively confirmed. The last observation of birds using the roost was on 7 June 2000, when 11 individuals were present. Later checks in July and August confirmed the absence of the species in the roost.

DISCUSSION

The first Egyptian Vultures were present at the roost approximately one and a half months after they arrived at the breeding grounds (beginning of March). This coincides with the species' incubation period, because laying usually takes place during the first half of April (Donázar 1993, pers. observ.). The birds seen in the first period were mostly adults; immatures joined the roost progressively at a later stage. The fact that the largest number of adults present were found in June (during the chick-rearing period) might correspond to their need to optimize foraging efficiency on food sources that are predictable in both space and time (Ceballos and Donázar 1988). On the other hand, adult birds that had failed in their breeding attempts and that had subsequently joined the roost might also cause this increase in numbers. The larger proportion of immature birds from May onward might be due to the late arrival of those non-breeding migrants, as has been suggested by Ceballos and Donázar (1990).

In this species, roosts may play a strong socialization role, as has been suggested in Black Vultures (*Coragyps atratus*; Parker et al. 1995). Associations are favored because they facilitate advantages in food finding and advantages in accruing coalition members in contests over food (Rabenold 1987, Parker et al. 1995). Social organization could facilitate the evolutionary stability among communally-roosting birds, but more data on this topic are needed.

Contrary to the dynamics observed in other Spanish roosts, where there is a progressive increase in birds from
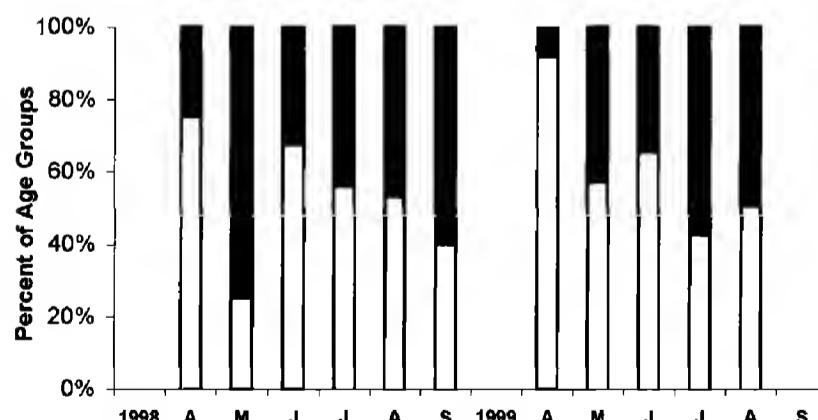
June–August (Ceballos and Donázar 1990, Donázar et al. 1996), in the roost that we studied, the largest number of birds was found in June of both years. The decrease in the number of birds present in July and August, much higher in 1999, might be linked to a progressive decrease in food availability in the area and by the increase in the availability in food resources in neighboring zones (e.g., Ebro valley). Low food availablity would have caused the displacement of birds to richer areas. In fact, the small numbers of birds observed in August–September 1999 was due to the fact that the food source they had been exploiting was progressively reduced (between March and May rubbish was dumped at the landfill site once a week, while between June and September no rubbish was dumped). Also, no food was available at all in July 2000 (pers. observ.). This lack of food, which would partly explain the observed differences in temporal pattern with respect to other roosts, may also explain the absence of observations of young of the year. These juveniles, having left their nests between the end of July and the beginning of August, did not visit the roost. Our results also differ from those obtained in island population; where, due to the species' sedentary habits, the largest concentrations take place in the period between October and February (de Pablo 2000, Donázar et al. 2002).

There seems to be a link between roosts that would be due to a socializing component in this behaviour rather than to food availability (Donázar et al. 1996). Even though use of roosts is dynamic and birds do visit other roosts in the same year, we believe that the disappearance of the roost was caused by the progressive decrease and total disappearance of the available food source. The formation of this roost coincided with the appearance of a food source that was available regularly in space and time (Margalida 1997), a factor that has also been recorded in other Spanish roosts (Ceballos and Donázar 1990, Donázar et al. 1996). The roost under study disappeared when no more food was available at the rubbish dump the birds had been exploiting. The roost was located on trees that were close to the food source and in an area with little human disturbance. These factors might have determined the selection of the specific roost site (Ceballos and Donázar 1990). However, contrary to other roosts located on isolated trees (Ceballos and Donázar 1990, Donázar et al. 1996) this selection did not occur until one year after the roost was formed. Our observations suggest that the formation and exact location of the roost might undergo a spatial selection process that would end in the choice of the most appropriate location.

Conservation Problems. The Egyptian Vulture roost we studied was formed in 1997 and disappeared in June 2000 just as the food source ceased to exist. This factor accounts for the disappearance of other roosts in Spain (Tella 1991), which shows the species' strong dependency on these roost sites and the importance that maintaining them may have in terms of conservation.

The species has undergone a 30% decline in the last 20 years in Spain (J. Donázar pers. comm.), so urgent measures are needed to reverse this trend. Egyptian Vulture survival might be closely linked to the maintenance and protection of roost sites, which are typically in quiet areas and close to predictable food sources (Ceballos and Donázar 1990, Tella 1991, Margalida 1997). A large part of the population decline might be due to the appearance of a nonnatural mortality factor such as poison. Protection of these areas is thus key to the conservation of the species. Also an important part of the non-breeding population concentrates at these roosts and exploits the available food. It is essential to protect the areas where the roosts are located and to maintain the food sources to which they are associated, as our results suggest that the roost will remain as long as there is an abundant and regular food supply. For this reason, solutions must be found that allow for the coexistence of the necessary sanitary regulations of waste dumps and the conservation needs of scavenging raptors (see Tella 2001).

RESUMEN.—Describimos la dinámica y variación temporal en la estructura de edades de un dormidero comunal de Alimoches en Cataluña. La formación y desaparición del dormidero coincidió con la aparición y desaparición de la fuente de alimento. El dormidero se formó a menos de 2 km de la fuente predecible de alimento de la cual se abastecían y cambió en varias ocasiones su ubicación. Los primeros individuos ocuparon el dormidero a finales de abril y las máximas concentraciones se produjeron en junio. Debido a la regresión sufrida por la especie durante los últimos 20 años y la importancia que tienen estos lugares para su conservación, es necesario proteger estos emplazamientos y compatibilizar la normativa sanitaria con el mantenimiento de los puntos de alimentación de los que dependen.

[Traducción de autores]

LITERATURE CITED

CEBALLOS, O. AND J.A. DONÁZAR. 1988. Actividad, uso del espacio y cuidado parental en una pareja de Alimoches (*Neophron percnopterus*) durante los periodos de dependencia de los pollos. *Ecología* 2:275–291.
——— AND J.A. DONÁZAR. 1990. Roost-tree characteristics, food habits and seasonal abundance of roosting Egyptian Vultures in northern Spain. *J. Raptor Res.* 24 19–25.
DE PABLO, F. 2000. Estatus del Alimoche *Neophron percnopterus* en Menorca, Islas Baleares. *An. Ornitol. Balears* 15:2–9.
DEL MORAL, J.C. AND R. MARTI (EDS.). 2002. El Alimoche

Común en España y Portugal (I Censo Coordinado). Año 2000. Monografía n° 8. SEO/BirdLife, Madrid, Spain.

DONÁZAR, J.A. 1993. Los buitres ibéricos. Biología y conservación. J.M. Reyero, Madrid, Spain.

———, O. CEBALLOS, AND J.L. TELLA. 1996. Communal roosts of Egyptian Vultures (*Neophron percnopterus*): dynamics and implications for the species conservation. Pages 189–201 *in* J. Muntaner and J. Mayol [EDS.], Biología y Conservación de las Rapaces Mediterráneas. Monografías No. 4 de la SEO, Madrid, Spain.

———, C.J. PALACIOS, L. GANGOSO, O. CEBALLOS, M.J. GONZÁLEZ, AND F. HIRALDO. 2002. Conservation status and limiting factors in the endangered population of Egyptian Vulture (*Neophron percnopterus*) in the Canary Islands. *Biol. Conserv.* 107:89–98.

MARGALIDA, A. 1997. Aparición de un dormidero comunal de Alimoche (*Neophron percnopterus*) en Cataluña (NE España). *Bull. GCA* 14:73–77.

———, D. GARCÍA, AND R. HEREDIA. 1997. Estimación de la disponibilidad trófica para el Quebrantahuesos (*Gypaetus barbatus*) en Cataluña (NE España) e implicaciones sobre su conservación. *Doñana Acta Vertebr* 24:235–243.

PARKER, P.G., T.A. WAITE, AND M.D. DECKER. 1995. Kinship and association in communally roosting black vultures. *Anim. Behav.* 49:395–401.

RABENOLD, P.P. 1983. The communal roost in Black and Turkey Vultures: an Information Center? Pages 303–321 *in* S.R. Wilbur and J.A. Jackson [EDS.], Vulture biology and management. Univ. of California Press, Berkeley, CA U.S.A.

———. 1987. Recruitment to food in black vultures: evidence for following from communal roosts. *Anim. Behav.* 35:1775–1785.

TELLA, J.L. 1991. Dormideros de alimoches en el Valle Medio del Ebro. Actas I Congreso Internacional sobre Aves Carroñeras: 69–74. AEDENAT-CODA, Madrid, Spain.

———. 2001. Action is needed now, or BSE crisis could wipe out endangered birds of prey. *Nature* 410:408.

DIET OF THREE SYMPATRIC OWLS IN STEPPE HABITATS OF EASTERN KAZAKHSTAN

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We studied the diet and food-niche overlap of three sympatric owls, the Eurasian Eagle-Owl (*Bubo bubo*), the Long-eared Owl (*Asio otus*) and the Little Owl (*Athene noctua*), during the breeding season in semiarid steppe habitats of eastern Kazakhstan and compared their food habits with other localities in the western Paleartic. These remote steppe habitats have been little studied and their breeding raptor communities resemble those of Mediterranean Europe.

STUDY AREA AND METHODS

The study was conducted between 12 and 28 June 1999 in eastern Kazakhstan in central Asia. The climate is continental, with very cold winters (when temperatures remain under 0°C for months), and warm summers. Such conditions can also be considered as arid or semiarid with annual rainfall <300 mm. Extreme temperatures and rainfall limit the growth of tree species (Walter 1981) and the landscape is dominated by steppe and semidesert

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Table 1. Number and percent occurrence in the diet of three owl species during the breeding season in eastern Kazakhstan. N = number of prey.

PREY ITEMS	EURASIAN EAGLE-OWL		LONG-EARED OWL		LITTLE OWL	
	N	PERCENT	N	PERCENT	N	PERCENT
Birds	54	17.3	2	2.5	8	4.1
Sturnus roseus	25	8.0	2	2.5	0	0
Falco naumanni	4	1.3	0	0	0	0
Unidentified	25	8.0	0	0	8	4.1
Reptiles	19	6.1	1	1.2	3	1.5
Lacertidae	2	0.6	0	0	1	0.5
Colubridae	9	2.9	1	1.2	0	0
Unidentified	8	2.6	0	0	2	1.0
Mammals	195	62.5	74	91.3	109	55.3
Microtidae	82	26.3	39	48.1	39	19.7
Muridae	12	3.9	27	33.4	8	4.1
Hemiechinus auritus	45	14.4	1	1.2	1	0.5
Sciuridae	39	12.5	6	7.4	8	4.1
Soricidae	1	0.3	0	0	0	0
Unidentified	16	5.1	1	1.2	53	26.9
Invertebrates	44	14.1	4	5.0	77	39.1
Coleoptera	13	4.2	2	2.5	53	26.9
Orthoptera	19	6.1	2	2.5	11	5.6
Unidentified	12	3.8	0	0	13	6.6
Total	312		81		197	

plains and hills with herbaceous vegetation and small bushes, whereas trees are confined to foothills of large mountains (Tian Shan in the south, Altai and Alatul in the east) or around human settlements and river valleys.

Pellets were collected in two different habitat types in the study area (Sánchez-Zapata et al. 2003): (1) *Seminatural* grasslands. Here the landscape was dominated by extensive livestock use and widespread croplands, but villages are small with <500 inhabitants. There are many abandoned fields and degraded steppe areas. (2) *Dry steppes*. This includes large areas of natural dry steppes with little or no human presence. Trees are lacking and the vegetation is dominated by grasses and forbs (*Artemisia* spp., *Limonium* spp., *Salsola* spp., *Ephedra* spp., *Haloxylon* spp.). There are also sparse rocky outcrops.

Fresh pellets were collected under perches around nests of the three species. Overall, we analyzed 108 pellets of the Eurasian Eagle-Owl collected in nine localities, 40 pellets of Long-eared Owls collected in two localities, and 107 pellets of Little Owls collected in four localities. All prey items were classified into 15 different categories (at the level of species, family, or order) included in four broad classes; birds, reptiles, mammals (Corbet 1978), and invertebrates. Diversity was quantified by means of the Levin's Index ($D = 1/\Sigma\ p_i^2$) whereas food niche overlap was calculated using the MacArthur-Levins's Index modified by Pianka ($O_{ij} = \Sigma\ p_{ki}p_{kj}/\sqrt{(\Sigma\ p_{ki}^2\ \Sigma\ p_{kj}^2)}$ (Marti 1987, Krebs 1989).

RESULTS

The diet of the eagle-owl included mostly mammals and birds (Table 1). The main prey species were voles (Microtidae) and medium-sized mammals such as hedgehogs (*Hemiechinus auritus*) and hamsters (*Citellus* sp., *Scirus* sp., *Alactaga* sp., *Pygerethmus* sp.) and Rosaceus Starlings (*Sturnus roseus*). Long-eared Owls preyed almost exclusively upon small rodents such as mice (Muridae) and voles, whereas Little Owls fed mainly on small rodents and invertebrates, mostly beetles (Coleoptera). The diversity of the diet of eagle-owls (D = 7.63) and Little Owls (D = 5.10) was higher than that of Long-eared Owls (D = 2.85). Food niche overlap was higher between eagle and Long-eared Owl (O = 0.73), than between Little Owls and the two other species (O = 0.58 and 0.47, respectively).

The diet of the eagle-owl was more diverse in steppe habitat than that found in Mediterranean countries, where the species feeds mainly on rabbits (*Oryctolagus cuniculus*), one of the staple food sources for top predators of Mediterranean ecosystems in Western Europe (Delibes and Hiraldo 1981). The absence of rabbits and the diurnal habits of similar medium-sized rodents in steppe habitats of Central Asia may be responsible for this difference. As a consequence, small rodents, hedgehogs,

and birds (including raptors) play an important role in the diet, similar to that found in other semiarid Mediterranean habitats when rabbits are scarce (Jaksić and Marti 1984, Serrano 2000, Martínez and Zuberogoitia 2001) and other semiarid or lower-latitude Nearctic biomes (Donázar et al. 1989, Marchesi et al. 2002).

Long-eared Owls had a similar diet to that reported for other populations in the Western Palearctic, with voles and mice as the main prey species, with the exception of a few localities in Mediterranean and suburban habitats where birds may also play an important role in the diet (García and Cervera 2001).

The diet of the Little Owl was also similar to that described in the Western Palearctic (Mikkola 1983), although invertebrates were more important in Mediterranean countries (Mañez 1983) and rodents were more important in temperate-climate areas including cold deserts (Herrera and Hiraldo 1976). Our results point out that despite regional differences in prey communities, owls did not show large intercontinental differences in food-niche metrics, as suggested in previous broader-scale studies (Marti et al. 1993).

RESUMEN.—Se estudia la dieta de tres rapaces nocturnas; el mochuelo (*Athene noctua*), búho chico (*Asio otus*) y búho real (*Bubo bubo*) en hábitats esteparios de Kazastán. Los restos de presas se obtuvieron del análisis de egagrópilas recogidas en las proximidades de los nidos durante el período reproductor. Los invertebrados y micromamíferos fueron la presa principal de *Athene noctua*, mientras que *Asio otus* predó casi exclusivamente sobre micromamíferos y *Bubo bubo* presentó una dieta muy diversificada, aunque basada en aves y mamíferos de mediano tamaño. La dieta de las tres especies fue más similar a la observada en latitudes templadas y desiertos fríos que a la descrita para ecosistemas mediterráneos semiáridos.

[Traducción de los autores]

LITERATURE CITED

CORBET, G.B. 1978. The mammals of the palearctic region. A taxonomic review. British Museum. Cornell Univ. Press, London, U.K.

DELIBES, M. AND F. HIRALDO. 1981. The rabbit as a prey in the Iberian Mediterranean ecosystems in western Europe. *In* K. Myers and C.D. McInnes [EDS.], Proceedings of the World Lagomoph Conference, Guelph, Canada.

DONÁZAR, J.A., F. HIRALDO, M. DELIBES, AND R.R. ESTRELLA. 1989. Comparative food habits of the Eagle Owl (*Bubo bubo*) and the Great-horned Owl (*Bubo virginianus*) in six Nearctic biomes. *Ornis. Scand.* 30:398–306.

GARCÍA, A. AND F. CERVERA. 2001. Notas sobre la variación estacional y geográfica de la dieta del búho chico. *Ardeola* 48:54–80.

HERRERA, C.M. AND F. HIRALDO. 1976. Food-niche and trophic relationships among European owls. *Ornis Scand.* 7:29–41.

JAKSIĆ, F.M. AND C.D. MARTI. 1984. Comparative food habits of Bubo owls in Mediterranean-type ecosystems. *Condor* 86:288–296.

KREBS, C.J. 1989. Ecological methodology. Harper & Row Publ., New York, NY U.S.A.

MÁÑEZ, M. 1983. Espectro alimenticio del Mochelo común (*Athene noctua*) en España. *Alytes* 1:275–289.

MARCHESI, L., F. SERGIO, AND P. PEDRINI. 2002. Costs and benefits of breeding in human-altered landscapes for the Eagle-Owl *Bubo bubo*. *Ibis* 144:164.

MARTI, C.D. 1987. Raptor food habits studies. Pages 67–80 *in* B.A. Giron Pendleton, B.A. Millsap, K.W. Cline, and D.M. Bird [EDS.], Raptor management techniques manual. National Wildlife Federation, Washington, DC U.S.A.

———, E. KORPIMÄKI, AND F.M. JAKSIĆ. 1993. Trophic structure of raptor communities: a three-continent comparison and synthesis. Pages 47–137 *in* D.M. Power [ED.], Current Ornithology, Vol. 10. Plenum Publishing Corporation, New York, NY U.S.A.

MARTÍNEZ, J.A. AND I. ZUBEROGOITIA. 2001. The response of the Eagle Owl (*Bubo bubo*) to an outbreak of the rabbit haemorrhagic desease. *J. Ornithol.* 142:204–211.

MIKKOLA, H. 1983. Owls of Europe. T. & A.D. Poyser, Berkhamsted, U.K.

SÁNCHEZ-ZAPATA, J.A., M. CARRETE, A. GAVRILOV, S. SKLYARENKO, O. CEBALLOS, J.A. DONÁZAR, AND F. HIRALDO 2003. Land use changes and raptor conservation in steppe habitats of Eastern Kazakhstan. *Biol. Conserv* 111:71–77.

SERRANO, D. 2000. Relationship between raptors and rabbits in the diet of eagle owls in southern Europe: competition removal or food stress. *J. Raptor Res.* 34:305–310.

WALTER, H. 1981. Los sistemas ecológicos de los continentes. Omega, Barcelona, Spain.

LETTERS

AN UNUSUAL CASE OF ADOPTION OF A GOLDEN EAGLE (*AQUILA CHRYSAETOS*) CHICK IN THE MALÁ FATRA MOUNTAINS, NORTHWESTERN SLOVAKIA

Golden Eagle (*Aquila chrysaëtos*) productivity was intensively studied in Slovakia in the period 1993–2000. Of nests containing at least two chicks that were not disturbed by man (*N* = 15), all exhibited brood reduction (Kropil and Majda 1996, Pages 486–494 *in* B.-U. Meyburg and R.D. Chancellor [EDS.], Eagle studies. WWGBP, Berlin, Germany; J. Korňan unpubl. data), which is high in comparison to other regions (McGrady 1997, Birds of the western palearctic, Update 1:99–114). Brood reduction was observed from hides or discovered when the nests were checked after the egg hatched and one chick was found killed. In addition, Golden Eagle productivity in Slovakia has been impacted by illegal nest thefts for decades (Korňan, M. et al. 1998, *Bird Crime in Europe* 4:11–13), which caused a 15–29% reduction in nesting productivity during the study period (*N* = 67). Therefore, nest wardens or guards were closely monitoring some sites (Korňan, J. et al. 1995, *Buteo* 7:163–168; Korňan, J. et al. 1996, *Buteo* 8:137–142). In order to reduce losses to brood reduction, the Slovak State Nature Conservation authorities manipulated two-chick broods to mitigate siblicide (cainism) and increase annual eagle productivity. The highest risk of cainism occurs when the chick is <6 d old; however, it may occur until the chick is ca. 2 wk old. In two-chick broods, the older or younger chick was taken into captivity and either hand-reared or reared by a foster parent (eagle or other raptor). Then after the period of 5–6 wk, the nestling was returned to the original nest to be reared by its natural parents or fostered into nests of other pairs (Hrtan and Mihók 1985, *Milvus* 2:71–76; Kulštrunk and Trpák 1987, Pages 235–238 *in* J. Sitko and P. Trpák [EDS.], Dravci 1985. Sborník z ornitologické konference Pøerov 14–16. 11. 1985, Státní ústav památkové péče a ochrany přírody v Praze ve spolupráci s Okresním vlastivedným muzeem J.A. Komenského, Moravským ornitologickým sdružením v Přerove ve Státním zemědělském nakladatelství v Praze. Praha, ČSSR; Šimák and Mihók 1989, pages 176–179 *in* J. Lukášek, I. Otáhal, and P. Trpák [EDS.], Záchranné chovy a odchovy Nový Jičín 1987. Státní ústav památkové péče a ochrany přírody v Praze ve spolupráci s Okresním vlastivedným muzeem v Novém Jičíne. Nový Jičín, ČSSR; Šimák and Mihók 1996, Pages 463–468 *in* B.-U. Meyburg and R.D. Chancellor [EDS.], Eagle studies WWGBP, Berlin, Germany).

This letter describes an unusual case of chick adoption by foster parents that had lost their offspring and nest due to severe weather. In fact, this is the first repeated chick adoption to the unoccupied nest ca. 690 m away from the original nest, which was destroyed. In addition, we note that the attempt to foster the chick to the original reconstructed nest was not successful. Finally, in the case we describe, there was an unusually long, 7-d period between the time of death of the original chick and time of adoption by the foster eagle pair.

As a result of heavy rain on the night of 26 May 2000, a Golden Eagle nest containing one 3-wk-old chick was dislodged and fell from the supporting tree. The nest was situated in a fir tree (*Abies alba*) near the village of Zázrivá, in the Malá Fatra Mountains, Slovakia. Two days later, a ranger of the Malá Fatra National Park checked the area around the nest tree, but was unable to find the chick. At 2000 H on the following day (29 May 2000) two rangers spent about 1 hr rebuilding the nest at the original location in the tree, using mainly material from the nest. Thick branches were used to improve stability, the nest cup was lined with green branches and prey remains (e.g., feathers, bones) were spread on the outer edge of the nest.

On 30 May 2000, a 3-wk-old Golden Eagle chick was removed from a nest containing a brood of two, and placed in the newly-reconstructed nest at 0530 H. A hide was constructed about 400 m away from the nest. Adult eagles were not seen near the new nest for the remainder of the day, and the chick was left on the nest overnight. On the morning of 31 May 2000 an adult female eagle was seen flying from the slope opposite the nest, but did not visit it. Later that day, we climbed the nesting tree to feed the chick. At 2030 H we took the nestling eagle from the nest because no eagles had visited the nest.

Despite the lack of success, we decided to make another attempt at fostering this chick to this pair. Before 1700 H, on 1 June 2000, the same chick was placed in an alternate nest in this eagle home range that was built on a cliff about 690 m from the nest that had collapsed (Fig. 1). The position of this nest, which had been successful in 1999, was quite open, and the chick in the nest could be seen from far away (probably ≥1 km). We restored and tidied up the nest cup. At 1440 H on 2 June 2000 an adult female Golden Eagle visited this nest, and immediately the nestling stood and begged for food. The female remained at the nest about 5 min. At 1600 H the female returned

Figure 1.   Locations of the original nest that failed (Nest 1) and the alternate nest (Nest 2) where a 3-wk-old chick was adopted by the resident pair of Golden Eagles near Zázrivá, Slovakia.

carrying rabbit-sized prey, and fed the chick for ca. 30 min and then flew away. Afterwards, the adult eagles attended the chick in a normal manner. The nestling fledged during the last week of July.

The first manipulations of Golden Eagle broods in Slovakia were carried out in 1978 (Šimák and Mihók 1996). The younger chicks were removed and fostered to other eagle pairs that had clutches destroyed, had abandoned unhatched eggs, or had suffered nestling mortality of a single-chick brood. Fostering was successful 74.3% ($N = 35$) of the time (Korňan, J. 1995, Buteo 7:163–168; J. Korňan unpubl. data; Korňan, J. et al. 1995, Korňan, J. et al. 1996) in the period 1993–2000. The fostering failures were caused by siblicide, natural predation, or unknown causes. One attempt to foster a chick to an empty nest was not successful, the chick was killed by the male and consequently eaten by both adult birds (Hrtan and Mihók 1985). According to the authors, the pair probably did not lay the clutch. The failure of this adoption was probably related to the nonbreeding condition of the pair.

Comparable adoption of an eagle chick to an unoccupied, alternate nest, as described in this letter, has not been described elsewhere as far as we could determine through our literature review. An adoption of a young Golden Eagle into a nest where the chick died and the nest was vacant for at least 2 d and possibly 5 d was conducted in the Snake River Birds of Prey Area, Idaho, U.S.A., in 1976 (M. Kochert pers. comm.). In this case, the foster chick was adopted and fledged successfully.

Siblicide and Cannibalism in the Booted Eagle (*Hieraaetus pennatus*) in the Tietar Valley, Central Spain

Facultative siblicide is assumed to occur in broods of the Booted Eagle (*Hieraaetus pennatus*; Simmons 1988, *Ibis* 130:339–357), although only minimal sibling aggression has been described in this species (Brown and Amadon 1968, Eagles, hawks, and falcons of the world. Country Life Books, London, U.K.; Steyn and Grobler 1981, *Ostrich* 52:108–118; Steyn 1982, Birds of prey of Southern Africa. David Philip, Johannesburg, South Africa). Furthermore, there are no records of cannibalism for this species. Here I report two instances of both siblicide and subsequent cannibalism recorded in the Tietar River valley (central Spain, 4°42'W, 40°40'N) in 2000, during observations made from hides. Detailed information of the study area can be found in García Dios and Viñuela (2000, *Ardeola* 47:183–190)

In a nest with two chicks, where observations started on 29 May 2000, the chicks were of similar size and about 5 d old. During my next visit (5 June), one chick was much larger than the other. On 7 June, the smaller chick had an obvious bare skin patch on its back, as if the down had been plucked out. On 8 June, the larger chick harassed and pecked the head and back of its sibling constantly; the adult birds were at the nest for short periods, but did not stop the sibling aggression. On the early morning of 10 June, the small chick begged less frequently and less loudly than during previous visits and the large chick pecked the smaller chick's head and back. A few hours later, presumably soon after the small chick died, the adult female started to feed the surviving chick with the remains of its sibling, providing 257 individual morsels.

The second record concerned a nest that contained two chicks about 2- and 4-d-old on 14 June 2000. Neither sibling aggression nor wounds were observed on that date. On 16 June, the female fed both chicks, but the small chick pecked at the head and back of its sibling repeatedly in the morning. On 18 June, the small chick initiated sibling aggressive behavior; the large chick pecked at its sibling less often but used more force. The adult female stopped the agnostic behavior by brooding both chicks. On 19 June, adults were not seen at the nest when I began observations. The small chick was more active than its larger sibling, it begged and moved around the nest, but no aggressive behavior was observed. The adult female brought one small prey, which was eaten by the large chick. Soon after, the small chick attacked but the large chick replied by pecking more often and also more forcefully than its sibling. This time, the female did not stop the sibling aggression. On 19 June, I climbed up the nest and found no prey remains. I made an examination of the chick's bodies and no wounds were observed, although the small chick was weak and emaciated.

On 20 and 21 June, I monitored the nest continuously from dawn to dusk and observed no prey deliveries to the nestlings. In the morning on 22 June, I observed the adult female pecking the head of the small chick, which seemed to be dead. During 4 hr the female brooded the two chicks. After that, she picked up the dead chick and started to feed the surviving chick, which was begging. The surviving chick ate 206 food morsels and the female 14. In this population of Booted Eagles, unlike in other areas (e.g., southern Africa; Steyn 1982), brood-reduction seems to be frequent; sibling aggression has been regularly observed in almost all of the nests monitored ($N = 21$) and at least two additional suspected cases of siblicide occurred during 2001.

BOOK REVIEW

Cool North Wind: Morley Nelson's Life with Birds of Prey. By Stephen Stuebner. 2002. Caxton Press, Caldwell, ID. xx + 431 pp., 17 color photographs, numerous black-and-white photographs. ISBN 0-87004-426-5. Cloth, $24.95.—Admirers of Morley Nelson will enjoy the stories told in this book, as will all other raptor enthusiasts. This account describes the life of a man of action, a man with a fierce passion for birds of prey. It traces his introduction to the family farm in North Dakota, where Morley first became acquainted with wild birds of prey, and his beginnings in falconry with a Red-tailed Hawk (*Buteo jamaicensis*) taken from a nest on the farm. From the first encounter with that hawk, there was no turning back for Morley. His life has revolved around birds of prey for more than seven decades, and the world is a better place for it. This book makes a case for inclusion of Morley Nelson among the world's all-time raptor "protectors," and in the process of ranking Morley Nelson's accomplishments in comparison with other notable conservationists, may actually do Morley a disservice.

Morley was born in 1917 and raised on a farm in North Dakota. Many of the experiences of living on a farm shaped his life, including lessons about killing animals for food, dealing with all sorts of animals, and overcoming hardships with resolve and determination. A defining moment in young Morley's life occurred while he rode his horse "Slim" across a pasture that held a pond. The horse inadvertently caused four Green-winged Teal (*Anas crecca*) to flush from the pond, and Morley was amazed to see a tremendously exciting phenomenon of nature: a Peregrine Falcon (*Falco peregrinus*) diving out of the blue, striking one of the teal with an explosion of energy and feathers, grabbing the teal out of the air, after inverting in flight, and flying off with it.

Later, Morley had opportunity to tell his father and grandfather about what he had seen, and he expressed a fervent desire to obtain a hawk and try to train it. With his father's blessing, Morley went out and located the nest of a pair of Red-tailed Hawks, and with a fair amount of effort, climbed the tree and pulled an eyas to take home. Morley used his own sensibility and ingenuity, and support from his father and grandfather, to figure out how to "man" the hawk, train it to hunt with him, and to take game on the family farm. Morley became a self-taught falconer and began at age twelve a lifelong pursuit that made him famous, led to his personal connections with governors and people in entertainment and high places, and enabled him to do what he could to educate the public and protect wild raptors and their habitats.

Cool North Wind describes the progress of Morley's life as a student at North Dakota State University, where he obtained a bachelor of science degree and specialized in soil science and hydrology. Morley answered an advertisement for a job with the Soil Erosion Service in New Mexico and moved there, where he was pleased to meet Luna Leopold, then a professor at the University of New Mexico. Contact with the son of famed ecologist Aldo Leopold made a lifelong impression on Morley.

The attack on Pearl Harbor pulled Morley, like many other Americans of his age, into World War II, and he became an officer in the famed Tenth Mountain Division. This elite Army division required very strenuous physical training in mountainous survival-type settings. Morley proved to be a perfect fit for this assignment, and he perfected mountaineering skills that later were very useful in climbing to Prairie Falcon (*Falco mexicanus*) and Golden Eagle (*Aquila chrysaetos*) nests. Morley eventually entered combat with his division and performed superbly, even when wounded in combat. Yet, he maintained a bit of a nonconformist streak, going absent without leave during a period of convalescence from a war wound in order to take a jeep ride to check out raptor nests in Yugoslavia.

Cool North Wind continues as it traces Morley's life after the war, his falling in love with his first wife, Betsy Ann, and the arrival of their three children. Morley resumed what was to become a very successful career with the Soil Conservation Service. But raptors and falconry continued to play a

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dominating role in his life. His children grew up with Prairie Falcons and Golden Eagles in the house, as well as Ferruginous Hawks (*Buteo regalis*) and many other raptors. Rehabilitation of injured raptors became a part of the "normal" life in the Nelson household.

Over the years, various unique challenges and opportunities presented themselves, as Morley became regionally and even nationally known for his work with birds of prey and his passion for them. Morley became a consultant in the preparation and filming of a number of feature films, including those made by the Disney Corporation. These films featured birds of prey that were trained by Morley and allowed for hunting and other spectacular aerial scenes that depicted the lives, natural history, and magnificence of various species of raptors. Morley and his sons eventually formed their own production company and have produced their own high-quality films featuring birds of prey. These fabulous film productions have educated the public on natural history of birds of prey, as well as promoting admiration, protection, and conservation of the birds and their habitats.

Morley was able to translate his intimate knowledge and appreciation of the unique Snake River nesting habitat as one of the richest breeding areas for birds of prey in North America into establishment of a National Conservation Area for these birds, which were at risk of losing their critical habitat to the growing agriculture industry. He was also hired by Idaho Power to help redesign power poles and structures to minimize dangers of electrocution to Golden Eagles and other large raptors. Morley used a mock power pole setup at his residence to experiment with his own live eagles and thus learn design techniques that would minimize risk of electrocution.

All the while, Morley used his voice and clout to call for an end to shooting of raptors and for an increase in facilities to care for sick and injured raptors. *Cool North Wind* tells some stories of altercations between Morley and citizens who made the mistake of threatening to shoot wild raptors, in which case harsh words were exchanged and fights were narrowly averted.

This book contains many, many good stories. But it has some flaws. Very little is said about the actual practice of falconry by Morley Nelson. Falconry is the taking of live quarry with trained birds of prey, and very little is said about Morley's hunting with

trained falcons, which detracts from the book's potential appeal to falconers. There are inaccuracies in the book, such as a story of Morley's training in the Aleutian Islands prior to WWII combat, where Morley encountered a Peale's Peregrine Falcon. The Peale's Peregrine is incorrectly described as an "arctic" subspecies of the Peregrine Falcon.

The principal flaw of this biography of such an impressive man is the attempt to rank his accomplishments with those of other raptor "protectionists." By making such an attempt, further scrutiny is invited. For instance, although it is true that Morley Nelson consulted with the power industry in Idaho to develop transmission facilities that would be safer for raptors, what is not emphasized is that by so doing, the power industry has been able to ward off federal regulation that could have imposed more stringent safety standards for raptors.

Even the successful preservation of the Snake River Birds of Prey National Conservation Area tells only part of the story. Compromises were made with local land users, including cattlemen and the Idaho National Guard, in order to obtain political consent to preserve the Snake River Birds of Prey Area from agricultural development. As a result, those "conservation" lands have never been managed primarily for the benefit of the resident birds of prey, despite the name of the BLM-managed area. Consequently, a tremendous negative change has occurred in the conservation area over the past few decades, and habitat is now altered considerably. Shrubsteppe habitats are highly degraded, invasive cheatgrass is reducing lagomorph populations, fire regimes have become catastrophic, Golden Eagle and Prairie Falcon numbers are in long-term decline, and no one has found a solution for protecting the Snake River Birds of Prey National Conservation Area from its own management. Morley Nelson is now well aware of the declines of eagles and falcons, and he surely appreciates that saving the lands from cultivation was not the permanent solution he might have hoped for.

As a biography of a fascinating life, this book deserves reading by all raptor enthusiasts. It provides a history of a man who truly is an American original. Morley Nelson has won respect from essentially everyone he has encountered during his long life, and his fierce passion for birds of prey has been contagious and inspiring to countless admirers from all walks of life.—**Stan Moore, 4220 Langner Avenue, Santa Rosa, CA 95407 U.S.A.**

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Raptor Research		0	8	9	2	–	1	0	1	6	

4. Issue Frequency	5. Number of Issues Published Annually	6. Annual Subscription Price
Quarterly	4	$33.00

7. Complete Mailing Address of Known Office of Publication (Not printer) (Street, city, county, state, and Zip+4)	Contact Person
Raptor Research 810 E. 10th Street P.O. Box 368	Karen Ridgway **Telephone** (785) 843-1234 ext. 138

8. Complete Mailing Address of Headquarters or General Business Office of Publisher (Not printer)

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13. Publication Title	Raptor Research	14. Issue Date for Circulation Data Below	July-03

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g. Total Distribution (Sum of 15c and 15f) ►			1199	1094
h. Copies not Distributed			177	156
i. Total (Sum of 15g. and h.) ►			1375	1250
Percent Paid and/or Requested Circulation (15c divided by 15g times 100)			99.8	99.8

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